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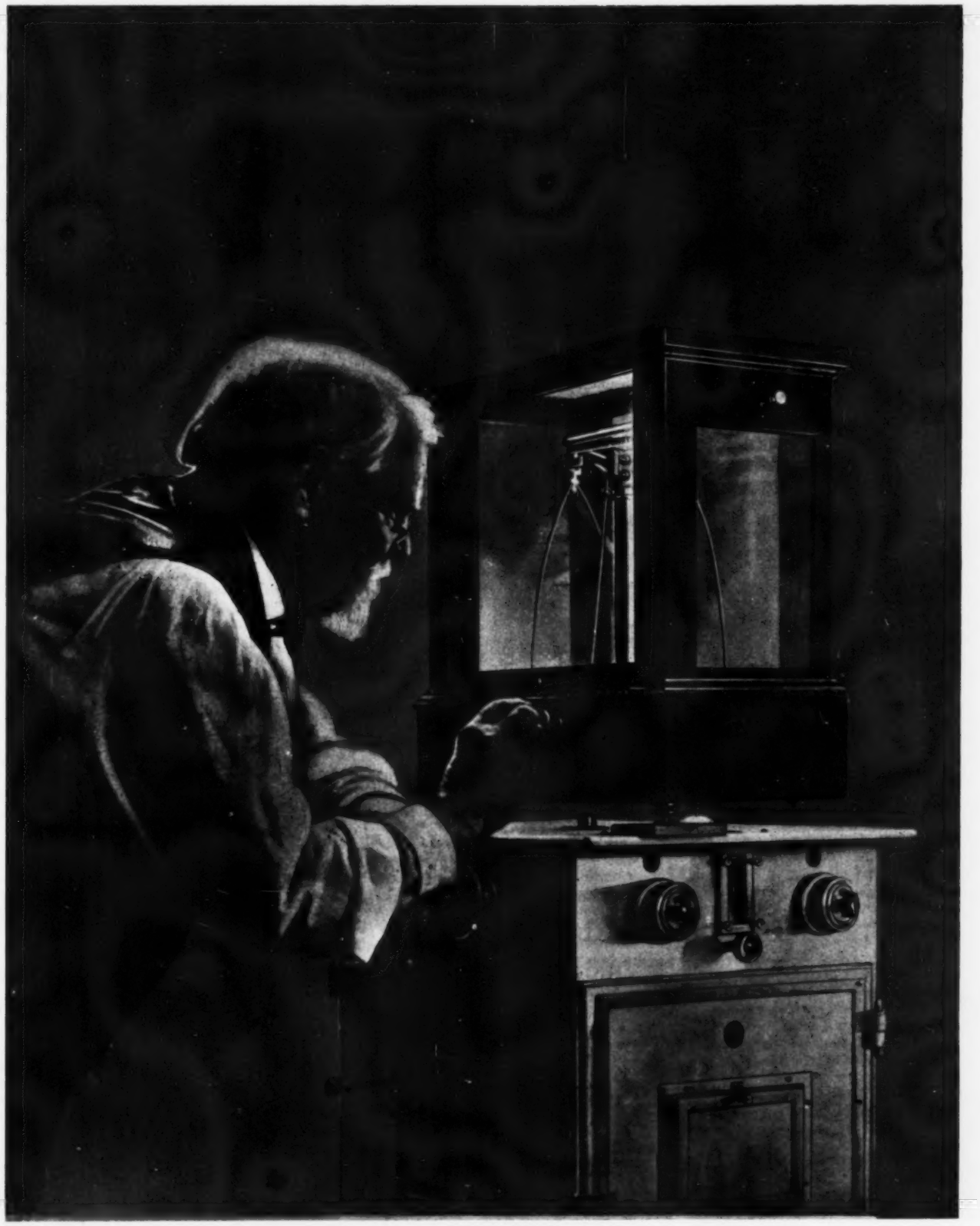

SCIENCE AND THE TARIFF

The duty assessed on many kinds of goods by the United States Customs depends on the weight, and this may vary considerably according to the weather. This is the case with cotton yarns, and, without special provisions, the duty levied on the same lot of yarn might easily vary 2 to 4 per cent, according to the weather on the day of entry. To overcome this discrepancy, all yarns are carefully dried until they are in the same condition of dryness. The above illustration shows the electric drying oven used, with delicate scales above by which the weighing is done.—[See page 199.]

Recent Evidence for the Existence of the Nucleus Atom*

Varied Theories Developed, but Much is to be Done to Furnish Definite Ideas

By Alfred D. Cole

THE great French scientist Poincaré,[1] just before his death two years ago, described an atom before the French Physical Society in these words:

"Each atom is like a kind of solar system where the small negative electrons play the role of planets revolving around the great positive central electron which takes the place of our sun. . . . Besides these captive electrons there are others which are free and subject to the ordinary kinetic laws of gases. The second class are like the comets which circulate from one stellar system to another, establishing thus an exchange of energy between distant systems."

Such an atom is a world in itself and strangely different from the kind we learned about in our text-books 20 years ago. One of the much used chemistries of that day put it in this way:

"An atom is the smallest portion of matter that can exist; it is incomprehensible, indivisible and in itself unchangeable."

How has this great change of view come about? How has the invisible unit evolved into the complex microcosm we now imagine? Time would fail us to trace all the steps of the way; we will attempt only to bring out some of the considerations which have in the past three years led many of our foremost thinkers to believe in that particular type of atom which we may call the nucleus atom. This type is similar to that which Poincaré pictured except that the central body is much smaller—very small indeed as compared with even the minute electrons which circulate about it.

We will recall first several of the discoveries which have forced us to abandon the idea of an indivisible atom. The fundamental one was Sir Joseph Thomson's discovery of the electron. In studying the nature of the cathode rays he found that they consisted of extraordinarily minute particles all exactly alike, whatever the nature of the gas within the tube might be. In a series of brilliant experimental studies he was able to show that the mass of one of these electrons was only one eighteen hundredth that of the lightest known atom. Then came Zeeman's discovery[2] that the separate lines of many spectra are broken up into two or more lines by the action of strong magnetic fields. The study of this effect made it quite certain that light radiation is caused by the rapid vibration of electrons in the luminous body. Therefore, electrons must be present in very many kinds of matter—probably in all. The electrons were early proved to carry a negative charge of electricity. Soon they revealed their presence in a great variety of ways and assisted in the explanation of widely different phenomena. But the corresponding positive constituent of matter proved singularly elusive although most diligently sought for, and it is only very recently that we seem to have traced it to its hiding place.

Different views regarding the nature of this positive constituent have led to much diversity of opinion regarding the structure of atoms. One of the most successful of these theories is that proposed by Sir Joseph Thomson in 1904.[3] He supposed a relatively large positive mass to exist—nearly as large as the atom—with the minute negative electrons distributed through it in such a way as to make the system a stable one. For easy mathematical treatment he assumed the electrons at equal distances apart in a series of concentric circular rings. To secure stability and illustrate certain atomic properties he supposed these rings to be in rotation. Thomson discussed many such configurations and satisfactorily explained many facts regarding the valency, the position in the periodic system, the electropositive or electronegative character and other chemical properties of different substances.

A modification of Thomson's atom was proposed by H. A. Wilson in 1911.[4] He supposes each negative electron to be situated at the center of a positive sphere of sufficient size to neutralize it electrically, and the atom to be made up of a group of such units, the total number being proportional to the atomic weight. In other words, Thomson's one relatively large positive mass is divided up into equal parts, each one containing a single negative electron. The mathematical development of this idea led to the result that the hydrogen atom contains eight such units. The gold atom would therefore contain about sixteen hundred of them.

In the Thomson and Wilson atoms, the positive portion is diffused throughout nearly the whole volume of the atom, a region about one hundred millionth of a centimeter in diameter. This type of structure has accounted for many atomic properties but has not been very successful in explaining the position of the lines in light spectra caused by vibrations in the atom.

I wish to direct your attention to-day more particularly to a type of atom in which the positive charge—equal as before to the sum of the charges of the negative electrons—is highly concentrated at the center of volume of the atom, occupying only an exceedingly small part of the volume. Nagaoka[5] had discussed the stability of such an atom in 1904. Sir Ernest Rutherford revived it in 1911 to explain phenomena observed by Geiger and Marsden,[6] and achieved a striking success. The facts observed were these; when α-rays were allowed to pass through thin sheets of metal, a small proportion of them were observed to be deflected through very large angles. Rutherford[7] made a theoretical examination of the results of a single encounter between an α-particle and an atom of the concentrated-nucleus type, and calculated the proportion of the α-particles which would be deflected through various angles by such encounters. Geiger[8] then made a new experimental study of the scattering produced by gold foil and found a very satisfactory verification of Rutherford's formula. From the amount of scattering at various angles, the value of the nucleus was also calculated. For gold it came out about 100 e. The general conclusion was reached that the nucleus charge is about one half the atomic weight times the charge of an electron. But Barkla[9] had earlier reached the same value for the sum of the electron charges—which in a neutral atom should equal the nucleus charge—by observations on X-rays and the use of a theory developed by J. J. Thomson. According to these views atoms contain only about 1/16 as many electrons as they do on the theory of H. A. Wilson.

On the assumption that large angles of deflection are sometimes due to single encounters with an atom, large forces must be postulated to swing the α-particles so considerably from their paths, forces so large as to require an approach to within an exceedingly small distance from the nucleus center. This distance was calculated to be about 1/3,000 of the atom diameter. If this is true, the nucleus can hardly have a diameter exceeding 1/5,000 that of the atom.

The view that an α-particle may turn through a large angle as the result of a single encounter was strikingly confirmed in 1912 by some remarkable photographs of the paths of α-particles through a gas, taken by C. T. R. Wilson.[10] I have here a reproduction of one of these photographs which shows two abrupt bends in the trail of a particle, one of 10.5 degrees and the other of 43 degrees. This second bend would certainly seem to be a case of "single scattering." The astonishing conclusion regarding the small size of the nucleus has been confirmed by some recent experiments of Marsden[11] in passing α-radiation through a gas.

A theory has been worked out by Darwin that when α-radiation entered hydrogen, a few H atoms would acquire from close encounters with the α-particles a velocity 1.6 times that of the striking α-particle, corresponding to a range four times that of the radiation. Marsden's experiments were undertaken to test this theory. He passes α-rays into hydrogen and observed the scintillations on a zinc sulphide screen placed at various distances. The range of the α-particles was found to be 20 cubic centimeters, but a few scintillations were found when the screen was as much as 90 cubic centimeters distant, due seemingly to the rapidly moving H atoms in their recoil from collision with the heavier α-particles. This was a striking confirmation of Darwin's theoretical calculations. Calculation by his method showed that the centers of the nuclei during collision were not over $1.7 + 10^{-13}$ cubic centimeter apart. This then would be the maximum value of the sum of their radii. This is smaller even than the former result and also smaller than the accepted value of the diameter of an electron.

Thus the nucleus of the atom appears to be extraordinarily minute, and this suggests an explanation of the somewhat paradoxical result, that practically all of the mass of the atom seems to reside in the nucleus. For if the size is extremely small its electromagnetic mass would—from the formula $2/3\frac{e^2}{a}$—be relatively large. So its mass might be 1,800 times that of the electron (and J. J. Thomson's experiments suggest that no positive carrier has a mass smaller than that amount) provided its diameter were only 1/1,800 that of the electron. From such consideration Rutherford[12] thinks it probable that the *nucleus of the H atom* is, in fact, the long-sought positive electron.

Attention has been forcibly drawn to the nucleus type of atom within the past year and a half by the extraordinary success it has had as interpreted by Bohr, Darwin and Moseley, in accounting for the exact position of lines in the spectra of gases. Their work has also served to bring into the limelight the earlier and perhaps equally striking work of J. W. Nicholson. In November, 1911, he published a paper[13] in which he assumed the existence of several elements with atoms of very simple and definite structure. One of these he called nebulium. In the neutral condition it was supposed to have a positive nucleus with charge 4 e, and around it at equal distances apart in a circular path, rotated four electrons each with a unit charge e. It might, however, lose one electron, when it would become positively charged, its three electrons now taking up new positions a third of a circumference apart. Similarly he supposed that the atom might take up more electrons, and have a negative charge.

He discussed mathematically the vibratory motions of such an atom and showed what kind of a spectrum the radiation would furnish. The theoretical analysis of the spectrum of his imaginary element nebulium showed that all the characteristic nebula lines of the Great Nebula in Orion, leaving out those due to hydrogen and helium, could be attributed to the vibrations of the nebulium atom, except two lines. On the very day he read this paper in England a German astronomer, M. Wolf,[14] presented a paper in Heidelberg which described the discovery that different lines of this nebula were due to radiation from different parts of the nebula, and that these two lines which Nicholson had found exceptional were due to a radiating source different from that of the other lines. Whereas almost all the lines were due to radiation from the bright ring of the nebula, these two lines were caused by radiation from different parts of the nebula, that for one of them coming from the dark central space and for the other chiefly from the outer edge of the ring. All other lines had their maximum brightness in the bright ring itself.

Another imaginary substance, which Nicholson named protofluorine, he succeeded in connecting in a similar way with the spectrum of the sun's corona.[15] This atom he supposes to have—when neutral—a nucleus 5 e with 5 electrons in a circular orbit about it. He analyzes its radiation on the assumption that it gives forth radiation energy in quanta, as Planck has supposed. He anticipates Bohr in the emphasis he gives to the idea of constancy of angular momentum in the rotating electrons. His calculations on this protofluorine atom account satisfactorily for the existence of 14 out of 23 lines of the corona spectrum, with an average difference of less than one part in a thousand between observed and calculated values. His calculations also show the magnitude of the positive or negative charge of the atoms originating the various lines. He concludes that in these primitive forms of matter—nebulæ and solar corona—very simple types of atom exist, much more simple doubtless and more amenable to calculation than are the atoms of most terrestrial substances. While the correspondence between his calculated spectra and those observed at Lick Observatory is not so close as is that between theory and observed spectra in the recent work of Bohr, it is important to observe that most of these results are obtained by means of established mechanical principles and without the use of such questionable assumptions as the brilliant young Dane cheerfully and confidently makes.

And now let us consider briefly the work of Bohr. This is set forth in four papers[16] published in the *Phil-*

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* Address of the vice-president and chairman of Section B, Physics, of the American Association for the Advancement of Science, at Philadelphia, December 29th, 1914.

[1] Poincaré, Annual Rep. Smithsonian Institution, 1912, p. 199.

[2] P. Zeemann, *Phil. Mag.*, 43, 226-239; 44, 55-60 and 255-259.

[3] J. J. Thomson, *Phil. Mag.*, 7, 237-265, 1904.

[4] H. A. Wilson, *Proc. Amer. Phil. Soc.*, 366 (1911); *Phil. Mag.*, 21, 718 (1911).

[5] Nagaoka, *Phil. Mag.*, 7, 445 (1904).

[6] Geiger and Marsden, *Proc. Roy. Soc. A.*, 82, 495 (1909).

[7] E. Rutherford, *Phil. Mag.*, 21, 669-688 (1911).

[8] H. Geiger, *Proc. Man. Lit. and Phil. Soc.*, 55, Pt. II., p. xx (1911); *Phil. Mag.*, 25, 604-623 (1913).

[9] H. Barkla, *Phil. Mag.*, 21, 648 (1911).

[10] C. I. R. Wilson, *Proc. Roy. Soc. A.*, 87, 277 (1912).

[11] E. Marsden, *Phil. Mag.*, 27, 824-830 (May, 1914).

[12] E. Rutherford, *Phil. Mag.*, 27, 488-499 (March, 1914).

[13] J. W. Nicholson, *Roy. Astron. Soc. M. N.*, 72, 49-64 (1911).

[14] M. Wolf, *Nature*, 89, 70 (March 21st, 1912).

[15] J. W. Nicholson, *Roy. Astron. Soc. M. N.*, 72, 139-150 (1911).

[16] N. Bohr, *Phil. Mag.*, 26, 1-25 (July, 1913); 476-502 (September, 1913); 857-875 (November, 1913); 27, 506-524 (March, 1914).

sophical Magazine between July of last year and March of the present year. He starts with the Rutherford atom, i. e., a minute positive nucleus with its system of electrons revolving about it, the mass of the atom resident chiefly in the nucleus and the number of electrons approximately equal to half the atomic weight. He admits the difficulty of securing stability in such an atom (as compared, for instance, with Thomson's 1904 atom), but thinks that this difficulty can be removed if we admit the insufficiency of the classical dynamics to explain phenomena involving atomic distances, and introduce Planck's quantum into the equations. He claims that this furnishes a basis not only for a theory of atomic constitution but for that of molecules as well. He differs from Nicholson radically in assuming that when in a state of uniform rotation, the electrons do not radiate. This is not in accordance with our ordinary electrodynamics. Each atom, according to Bohr, has a number of "steady states" during which the electrons revolve uniformly and there is no radiation. But in passing from one steady state to another an electron winds inward toward the nucleus with its frequency increasing. Its acceleration meanwhile causes radiation, until the electrons settle into another steady state and cease for the time to radiate. In its stable state the angular momentum of every electron is the same. This agrees with Planck's idea of discontinuous radiation and the amount radiated in one emission for a vibrator of frequency ν is $\tau h\nu$ where τ is some integer and h is Planck's "universal constant." Bohr finds the equation for the relation between the frequency, mass of an electron, charge of electron, τ and τ. When τ is made 2 in the equation, Balmer's series for hydrogen is obtained, and for $\tau=3$ the infra-red series which Ritz anticipated and Paschen found. $\tau=1$ gives a series of lines in the ultra-violet and $\tau=4$ and 5 in the infra-red, neither of which has yet been observed. The lines observed by Fowler and by Pickering he connects with helium instead of with hydrogen.

From this equation he also calculates Rydberg's number N degrees and obtains 3.26×10^{15}. Its observed value is 3.29×10^{15}, so that the agreement of theory with observation is satisfactory. The theory further requires that very low gas density be required for numerous spectrum lines and very great gas volume for sufficient intensity. This probably accounts for the fact that 33 lines of the Balmer series for hydrogen can be seen in celestial spectra while only 12 appear in terrestrial (vacuum-tube) spectra.

From the work of Barkla and of Geiger and Marsden on the scattering of radiation Bohr accepts the view of van der Broek that the number of electrons in an atom in the neutral state indicates the position of the element in the periodic table. Thus he gives hydrogen one electron, helium two, lithium three, beryllium four, etc. The same number expresses the magnitude of the positive charge on the nucleus.

It is difficult to pass upon the validity of some of Bohr's assumptions. So high an authority as Jeans[17] calls it "a most ingenious and suggestive, and I think we must add, convincing explanation of the laws of series spectra," and yet he adds a little later that the only justification for the assumptions Bohr makes is "the very weighty one of success." Rutherford cautiously observes:

"The theories of Bohr are of great interest and importance as a first attempt to construct atoms and molecules and explain their spectra."

The views of Rutherford and Bohr regarding the structure of atoms are strongly supported by some striking experiments of Moseley published during the past year.[18] His works utilize the methods worked out by W. H. and W. L. Bragg[19] for measuring the spectra obtained by reflecting X-rays from the faces of crystals. Barkla and Sadler[20] showed in 1908 that if X-rays from an ordinary tube fall on different metals, "characteristic X-rays" are given off—these being different for each metal. Many metals can give out at least two different types of radiation. Barkla called these the "K series" and the "L series" radiations. For each metal the "K" radiation is about 300 times as penetrating as the "L" radiation. Kaye[21] has shown that an element excited under suitable conditions by rapid cathode rays gives out a considerable portion of the X-rays produced in the form of characteristic rays.

Moseley photographed the spectra obtained by using a great variety of different metals as targets for cathode-ray bombardment. The X-rays so produced were reflected from a crystal face and then fell upon the photographic plate. Spectra of the third order showing fine sharp lines were obtained. Similar results were secured for over 40 metals. For the elements of lower atomic weights, each spectrum showed two prominent lines, and the spectrum of any element was almost exactly like that of the element next below it in the periodic table except that it was shifted in the direction of shorter wave length by about the distance between its two lines. The radiation was of the "K" type. Thus a close relation was established between the X-ray wave-length and chemical properties. Further, the frequency of the principal line was found to be proportional to $(N-a)^2$, where N is an integer and a is a constant equal to about unity. N is called the atomic number of the element. Thus it is 20 for Ca, 22 for Ti, 23 for Va, 24 for Cr, 25 for Mn, 26 for Fe, 27 for Co, 28 for Ni, 29 for Cu, 30 for Zn, etc. These numbers are very nearly in the orders of the increasing atomic weights, but more exactly in the order of Mendeleeff's periodic table. The numbers then correspond with the changes in chemical properties more nearly than do the atomic weights. For instance, we have Fe, Co, Ni representing both the chemical order and order of the atomic numbers (26, 27, 28), while Fe, Ni, Co is the order of increasing atomic weights. It thus appears that this atomic number is a more fundamental quantity than is the atomic weight, or as Soddy[22] has put it,

"It is the nuclear charge rather than the atomic mass, which fixes the position of the element in the Periodic Table."

A. van der Broek[23] had before this suggested that the total number of unit charges on the electrons of an atom is the number representing the position of the element arranged according to increasing atomic weight. But in a neutral atom the sum of the (negative) charges on the electrons should equal the positive charge on the nucleus, so that the two statements amount to the same thing.

When the experimental values found for the frequency were compared with those indicated by Bohr's theory, the agreement was found to be a remarkably close one.

With elements of higher atomic weight Moseley obtained spectra whose lines indicated the Barkla "L type" of radiation. The atomic numbers calculated from the positions of the strongest lines of these "L" spectra ranged from 40 for zirconium to 79 for gold. These experiments then give strong support to the hypothesis of van der Broek that the total charge of the electrons of an atom indicates its position in the periodic system. Known elements were found to correspond with all the numbers from 13 to 79 except three, indicating that three elements probably remain to be discovered. The wave-lengths of the characteristic X-rays from the metal is of the order of 1/1,000 that of visible light (i. e., about 40 waves in 0.000001 inch).

During the past few months Rutherford and Andrade[24] have extended these methods of crystal reflection to the study of radiation from Ra-B Ra-C. The γ-ray spectrum of Ra-B was found to be of the same general type as that of the X-ray spectrum from various heavy metals when bombarded by cathode rays. The result for soft γ-rays from Ra-B shows that its radiation belongs to the "L series" for heavy metals. Moseley's formula applied to the measurement of the lines of the γ-ray spectrum gave $N=82$, which is the atomic number of lead. The atomic weight of Ra-B is, however, 214, while that of lead is 207. This difference is nevertheless fully explained by a new generalization of Soddy and Fajans which we will presently notice. The experiments described in the second paper were made with much more penetrating γ-radiation from both Ra-B and Ra-C. This penetrating γ-radiation from Ra-B was found to correspond to the K series for the same metal, lead. The still more penetrating radiation from Ra-C has a line spectrum of still higher frequency than the K type, for which the name "H" series is suggested. These rays are especially interesting because they have by far the shortest wave-length yet known, only about 1/8 of the wave-length of the shortest X-ray waves measured by Moseley or about 1/80,000 of the wave-length of sodium light. Rutherford in his comments on these waves very justly remarks, "It is surprising that the architecture of the crystals is sufficiently definite to resolve such short waves."

During 1913 some remarkable work on the relations of radioactive substances to each other has given support to the nucleus atom from an unexpected quarter. Fleck,[25] Russell,[26] von Hevesey, [27] Fajans[28] and Soddy[29] have all had a share in this work. They have found that when a radioactive substance ejects an a-particle a substance of different chemical properties and different valency results. The new substance lies two columns to the left in the periodic table, has an atomic number two less and an atomic weight about four less than the parent substance. If, however, the radioactive substance ejects a β-particle or electron, the new substance is one column to the *right* in the periodic table, increases one in atomic number, and does not change in atomic weight. Plainly then two or more elements may occupy the same position in the periodic table, for if an element loses in succession—in any order—two β-particles and one a-particle, its atomic number will be again the same as it was at first. Thus Ra-D has the atomic number 82; it loses a β-particle and becomes Ra-E with atomic number 83; this loses another β-particle and becomes Ra-F with atomic number 84; this finally loses an a-particle and becomes lead, with the original atomic number 82. The series Ur1, UrX1, UrX2 and Ur2 is of the same kind, except that the particles are ejected in the reverse order, a, β, β. So the old difficulty of finding places in the periodic table for the 34 radioactive substances now known has disappeared, since they have but ten different atomic numbers and require therefore but ten places in the periodic table. Soddy has introduced the term isotopes to designate two elements occupying the same place in the table. Isotopes are chemically inseparable and probably have identical spectra, but they have different atomic weights.

It is evident that much remains to be done before we have very definite ideas of the structure of the nucleus atom. Many questions are entirely unanswered. For example, in how many rings do the electrons lie? For hydrogen and helium as for nebulium and protofluorine (if they exist) the electrons are so few that they doubtless all lie in one ring, but there are reasons for believing that in atoms of higher atomic weight there are two or more rings. With a large number of electrons present—with the 100 electrons of the gold atom for instance—there may indeed be several configurations which will satisfy the conditions of stability. Even for comparatively light atoms Bohr[30] supposes that as many as five rings exist. Again, from what part of the atom of a radioactive substance do these ejected a- and β-particles come? Soddy[31] believes that both originate in the nucleus, but that the chemical and the electrochemical properties are controlled by the outer ring of the electrons. Moseley regards the similarity of the X-ray spectra of different metals as satisfactory evidence that such radiation originates inside the atom, while light radiation is determined by the "structure of the surface." Rutherford[32] and Bohr both raise the important question whether atomic nuclei contain electrons, and both conclude that they do. These and many other questions have already been asked but only tentative and provisional answers have thus far been given. Doubtless there is a field here for much important experimental and theoretical work in the immediate future—a field which American physicists will seek to cultivate with their European brethren, who have done about all of the work thus far.

These hasty considerations perhaps suffice to show the varied character of the lines of evidence that have been developed during the past three years to give support to some form of nucleus atom. Radioactive phenomena, X-ray radiation and chemical properties seem to give united testimony for it. Doubtless the final type of atom has not yet been described, for it is easy to criticise the views of Nicholson, of Bohr or any other who has proposed a model, but it is probable that some form of nucleus atom will soon receive general recognition.

Behavior of Incandescent Lamps

In the circular on fees for tests issued by the Bureau of Standards the following facts are stated in relation to the behavior of the films of incandescent lamps:

A normal carbon filament incandescent lamp which operated at constant voltage increases slightly in candlepower for the first 50 hours, more or less, according to the temperature at which it is burned. A stationary period is then reached, after which there is a progressive drop in the candlepower. The initial rise in candlepower is due to a gradual decrease in the resistance of the filament, while the subsequent decrease in candlepower is due chiefly to blackening, caused by a deposit on the inside of the bulb.

This is, in general, the behavior of all incandescent filament lamps, whether carbon, metallized carbon, tantalum, or tungsten. Therefore, in order that a lamp may be useful as a photometric standard it should be carefully seasoned by a preliminary burning sufficient to bring its resistance to a steady state. In order that it may not be affected subsequently by any slight overvoltage, the lamp should be seasoned at a voltage somewhat higher than that at which it is to be used as a standard.

[17] J. H. Jeans, *Report B. A. A. S.*, Birmingham, 1913, 376.

[18] H. G. J. Moseley, *Phil. Mag.*, 26, 1024-34 (1913); 27, 703-713 (1914).

[19] Bragg and Bragg, *Proc. Roy. Soc. A.* 88., 428 (1913), and 89, 246 (1913).

[20] Barkla and Sadler, *Phil. Mag.*, 16, 550-584 (October, 1908).

[21] G. W. C. Kaye, *Phil. Trans. Roy. Soc. A.*, 209, 123 (1909).

[22] F. Soddy, "The Radioelements and the Atomic Law" (Longmans, 1914), p. 41.

[23] A. van der Broek, *Physik. Zeitsch.*, 14. 32 (1913).

[24] Rutherford and Andrade, *Phil. Mag.*, 27, 854 (May, 1914), and 28, 263 (August, 1914).

[25] A. Fleck, *Trans. Chem. Soc.*, 103, 381 and 1052 (1913).

[26] A. S. Russell, *Chem. News*, 107, 49 (January 31st, 1913).

[27] G. von Hevesey, *Physik. Zeitsch.*, 14, 49 (January 15th, 1913).

[28] K. Fajans, *Physik. Zeitsch.*, 14, 131 and 136 (February 15th, 1913).

[29] F. Soddy, *Chem. News*, 107, 97 (February 28th, 1913); *Jahrb. Radioakt.*, 10, 188 (1913).

[30] N. Bohr, *Phil. Mag.*, 26, 496 (1913).

[31] F. Soddy, "The Radioelements and the Atomic Law" (Longmans, 1914), p. 39.

[32] E. Rutherford, *Phil. Mag.*, 27, 488-490 (Ma ch, 1914

Watching the Earth Revolve

An Apparatus That Enables the Movements of the Earth to be Directly Studied

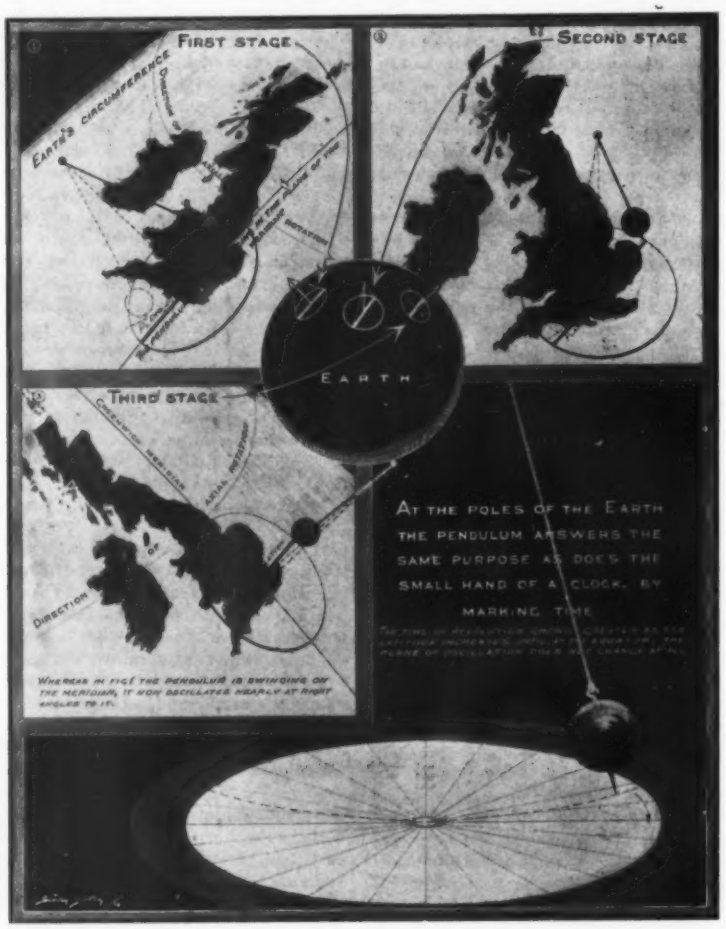
By Arthur H. Compton

For most people the fact that the sun rises in the morning, travels slowly across the sky and sets in the evening is sufficient evidence that the earth goes around. Our ancestors, however, believed for the same reason that the sun and moon and stars all actually move across the sky while the earth itself stands still. Indeed, the attempt of Copernicus and Galileo to dispel this idea, which seemed so evident as to be almost axiomatic, was the cause of their bitter persecution. It is really impossible to prove definitely by means of observations on the heavenly bodies whether the earth really revolves while the stars remain fixed or whether it is the stars which revolve about the earth. Even though we may show that these bodies are millions or trillions of miles from us, we can still explain their apparent daily motion by keeping the earth at rest if we suppose that the stars are traveling through the heavens with a sufficiently great speed. In fact, this is the assumption on which Ptolemy based his theory of the universe.

It was not until the middle of the last century that Foucault performed his famous pendulum experiment in the Pantheon at Paris (Fig. 1), which was the first good proof that the earth is actually revolving.[1] Even his experiment, however, did not show that all the apparent motion of the stars across the heavens is due to the turning of the earth. Since a pendulum swings in a vertical plane, it is only the part of the earth's rotation about a vertical axis which Foucault's apparatus was able to measure. Suppose that the pendulum is set up at the point O (Fig. 2) on the earth's surface. It is evident that there will be some rotation about the vertical axis OZ, but this will be less rapid than the rotation about an axis OP, parallel to the earth's axis. If the earth turns around the axis $O'P'$ once in 24 hours, there ought to be a rotation about a vertical axis at Paris, whose latitude is 49 degrees, at the rate of once in about 32 hours; and by means of his enormous pendulum Foucault showed that such a rotation actually exists. But the fact that there is such a rotation about the vertical axis does not show what the real angular velocity of the earth is nor the direction of the axis about which the earth turns. For example, a comparatively small rotation about such an axis as $O'M$ would give the same effect on Foucault's pendulum as a much more rapid rotation about the axis $O'P'$. In order to show that all the apparent motion of the stars across the sky is due to the earth's rotation, it is necessary to determine, without observations on the stars, how fast the earth is revolving, and where its axis is located. This requires more data than are given by Foucault's experiment.

If we can measure the rotation about two horizontal axes, OX and OY, as well as about the vertical axis OZ, the earth's rotation will be completely determined. For by combining the rotation about the OX and the OY axes, the rotation about a north and south axis ON can be found, and combining this rotation with that about the vertical axis the true rate of the earth's rotation about OP can be calculated. It is evident that by comparing the relative magnitudes of the rotation about the OX and the OY axes the angle ψ, or the azimuth of the X axis can be obtained, and from the ratio of the rotations about ON and OP the angle ϕ, which is the latitude of the observer, can be determined. Thus, if the rotation about these three axes is measured, not only the length of the day, but also the position of the true north and the latitude can be calculated, and this wholly independent of astronomical observations.

The earth rotation ring shown in the photographs was made for the purpose of measuring these three components of the earth's rotation. The principle on which this apparatus works is comparatively simple. The instrument consists essentially of a circular tube filled with water and mounted on an axis in its own plane, as in Fig. 3. This apparatus is set in a plane perpendicular to the axis OC, about which the earth's rotation is to be measured. If the rotation is in the direction indicated by the solid arrows, it will be seen that the side A of the ring is moving toward the left relative to the other side, and after the ring has been standing a few minutes the water within the tube has the same sort of motion. Now let the ring be quickly turned half way around about its axis, so that the part A comes to the nearer side, as shown by the dotted lines. It is evident that the water in that part of the tube will retain a large part of its original motion toward the left, so that there will be a relative motion between the water and the microscope, which turns with the earth. The speed of this relative motion will of course depend upon how fast the earth is revolving about the


FIRST STAGE
SECOND STAGE
THIRD STAGE
EARTH
AT THE POLES OF THE EARTH THE PENDULUM ANSWERS THE SAME PURPOSE AS DOES THE SMALL HAND OF A CLOCK, BY MARKING TIME
DIRECTION

By courtesy of the *Illustrated London News*.

Fig. 1.—Foucault's pendulum, which was the first satisfactory means of showing that the earth actually revolves.

[1] This experiment is described in the SCIENTIFIC AMERICAN, February 14th, 1914.

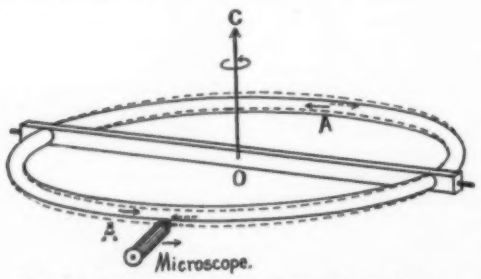


Fig. 3.—If the earth is revolving about the axis OC, when the ring is reversed there is a relative motion between the water and the microscope as shown by the dotted arrows.

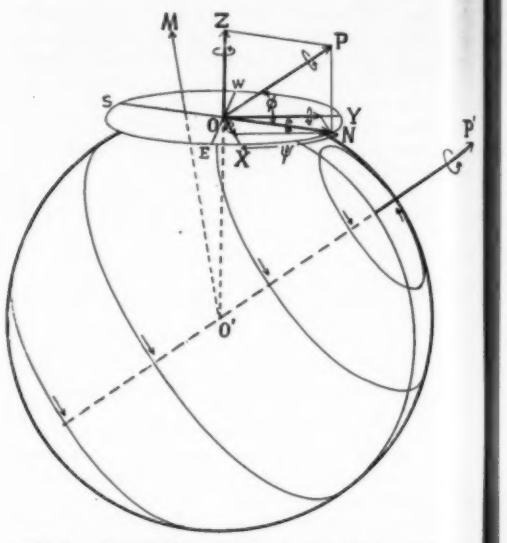


Fig. 2.—Foucault's pendulum was able to measure the earth's rotation only about a vertical axis OZ, while the earth rotation ring measures the rotation about the three axes OX, OY and OZ.

The actual length of the day can then be calculated, which was impossible from Foucault's experiment, and the latitude and the position of the true north can also be determined.

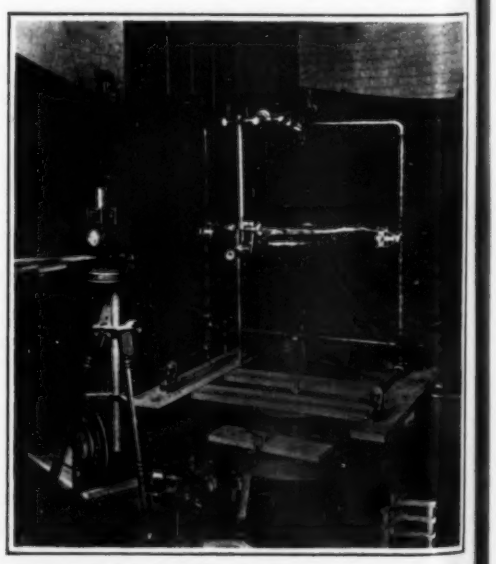


Fig. 6.—Measuring the absolute magnitude of the earth's rotation about a vertical axis.

axis *OC* as well as upon the dimensions of the ring. With the apparatus here described the motion was usually about as fast as that of the minute hand of a watch, and could easily be seen through the microscope.

The ring used in these experiments was made of 1-inch tubing, bent into a circle a foot and a half in diameter. Where the windows were placed the tube was constricted somewhat so as to increase the velocity of the water which was being watched. The motion of the water which filled the tube was made visible by shaking up with it a mixture of coal oil and carbon

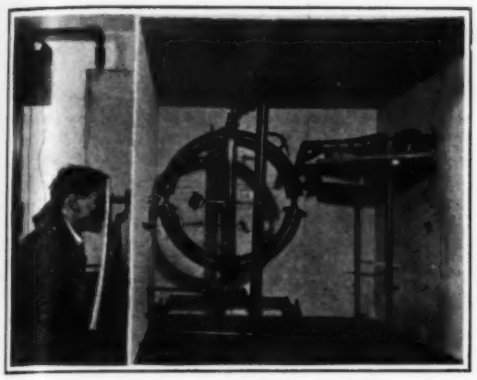


Fig. 4.—Watching the earth revolve. The apparatus is in a constant temperature room just above freezing point to avoid convection currents in the water.

tetrachloride of the same density as water, which formed small suspended globules whose motion was easily visible through the observing microscope. In order to avoid spurious motions due to differences in temperature in different portions of the tube, some parts of the experiment had to be performed with the apparatus boxed up in a cold room, as in Fig. 4, but in measuring the effect due to the vertical component of the earth's rotation, as in Figs. 5 and 6, no such particular precautions had to be taken.

When the ring was held in a vertical plane, as in Fig. 4, the oil globules are always seen to rise on the east side of the tube and go down on the west side, after the ring is reversed. This shows conclusively that the earth is turning over from West to East. Similarly, if the ring is in a horizontal plane, a motion to the left is always observed, which, as we saw above, indicates a motion of the earth in a counter clockwise direction about a vertical axis. It is an interesting experiment to project the motion of the oil globules through the microscopes onto a screen, with the apparatus set up as in Fig. 5. In this manner a room full of people can be shown a moving picture of the earth going around.

As an average of a number of readings, the ratio of the velocity observed about the *OY* axis to that about the *OX* axis indicated that the true north was 61.3 degrees from the *OX* axis, and when the motion about the vertical axis *OX* was determined, the latitude ϕ was found to be 42.8 degrees. In order to find out from these figures how fast the earth is going around, the apparatus was set up as in Fig. 6, keeping the ring in a horizontal position in order to measure the earth's rotation about a vertical axis. The spectrometer table upon which the apparatus was placed could be turned at any desired speed by means of the driving clock *C*. First a set of readings was taken with the clock stopped, and the motion of the globules to the left was measured. Then the clock was started, and was so adjusted that the globules moved just as fast toward the right as they had moved before toward the left. It is evident that the spectrometer table was then turning backward twice as fast, relative to the earth, as the earth itself was turning forward. The spectrometer table was turning at the rate of 1.346 times per day, which means that the earth is turning about a vertical axis at the rate of 0.673 revolutions per day. Since the ratio of the rotation about this axis to that about *OP* was already known, it was easy to calculate that the rate of the earth's rotation about its axis is 0.991 revolutions per day. That is, the length of the day, according to these data is 24 hours and 12 minutes.

It is interesting to compare these values of the azimuth, the latitude and the length of the day with their values as determined astronomically, thus:

	By data from earth rotation ring.	By astronomical data.
Day	24.2 hours	24.0 hours
Latitude	42.8 degrees	40.4 degrees
Azimuth	61.3 degrees	59.9 degrees

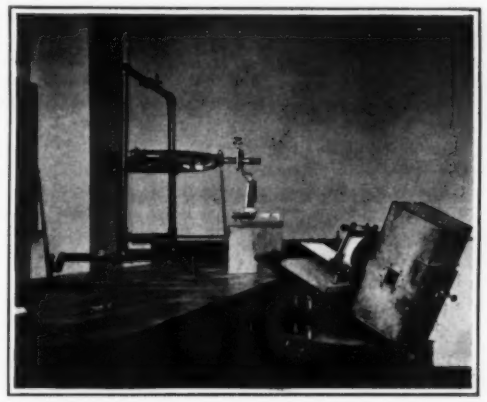


Fig. 5.—The apparatus set up with a projection lantern for showing real moving pictures of the earth's rotation upon a screen.

These figures show conclusively, within the limit of experimental error, that the earth turns about an axis which is identical with its astronomical axis, and that the rate of its rotation is that determined by astronomical observations. Thus it is evident that it is the earth alone which revolves, while the stars remain relatively fixed.

The Koepsel Permeameter*

THE moving coil galvanometer and many other electrical instruments built on the same principle consist essentially of a coil of wire suspended in a magnetic field. This coil experiences a torque which is proportional to the product of the current in the coil and the component of the magnetic field in the plane of the coils. In the instruments just mentioned the magnetic field is constant and the current varies. The deflection due to the torque thus becomes a measure of the current strength.

Instead of using a constant magnetic field, we may maintain a constant electric current through the moving coil and use this system for the measurement of the magnetic field. If this magnetic field is due to an electromagnet, the magnitude of the field depends upon the magnetomotive force applied and the material of the magnetic circuit. An electromagnetic system of this kind may therefore be made the basis of an apparatus for the determination of the magnetic properties of iron and steel.

Robinson[1] in the *Electrical World* of February 24th, 1894, gave a complete description of a permeameter based on this principle. However, he had not actually built the instrument.

Three days later Koepsel[2] described before a German electrotechnical society substantially the same piece of apparatus, which he had built and was actually using. This apparatus, as later improved by Kath,[3] is widely used, both in this country and abroad. It is sometimes called the Siemens and Halske permeameter, from the name of the manufacturer.

Orlich[4] at the Reichsanstalt determined a number of hysteresis loops with the Koepsel instrument and also by the magnetometer method, using ellipsoidal specimens for this latter test. His data show that at inductions of 15,000 gausses the instrument gives values of the magnetizing force which are too high. All values of the coercive force, as obtained by this instrument, are greater than those of the magnetometer. The shearing curves differ for different materials. Rohr[5] compares hysteresis data obtained by the Koepsel permeameter with that obtained by the watt-meter method and finds that the values of the Steinmetz coefficient thus obtained are in substantial agreement.

Much of the data on the magnetic properties of iron and steel have been determined with this apparatus. It seems, therefore, well worth while to give the Koepsel permeameter a careful experimental examination with a view to determining its reliability for use in making magnetic measurements.

As a result of the experiments conducted, the following conclusions were drawn:

The Koepsel permeameter has several valuable characteristics. It gives direct readings of the magnetizing force and the magnetic induction, both for normal induction and for hysteresis data. It is easy of manipulation and does not require greater care than the usual deflection instruments. It repeats its readings as consistently as could be desired. The readings may be very useful in indicating relative values of different materials or the degree of non-uniformity of similar materials. The fact that the observed values of the magnetizing force may differ by as much as 100 per cent from the true values does not destroy the value of this instrument for purposes of comparison.

From the experimental consideration of the different factors which may affect the accuracy of the readings the following detailed conclusions were drawn:

1. Readings on the two sides of the zero of the instrument may differ considerably, but the mean of the two values thus obtained shows satisfactory consistency on repetition.

2. Shearing curves for different grades of material show that the correction to be applied to the observed magnetizing force is not constant for a given induction, but depends upon the nature of the test specimen. This correction is usually subtractive for points below the knee of the induction curve and additive for points above the knee.

3. An increase in the cross-section of the test specimen tends to increase the observed values of the magnetizing force for points below the knee of the induction curve, and to decrease the observed values for points above the knee.

4. The length of the specimen projecting beyond the yokes produces no noticeable effect for points below the knee of the induction curve. For points above the knee the projecting ends increase the observed value of the magnetizing force.

5. If the bushings are not pushed all the way into their proper position, a higher apparent value of the magnetizing force is observed, due to the increased length of the portion of the bar under test.

6. Hysteresis loops obtained by the Koepsel permeameter always show a low observed residual induction and a high observed coercive force.

7. A theoretical and experimental study of the distribution of the magnetic fluxes through different parts of the magnetic circuit shows that shearing curves of the form observed are to be expected.

If the apparatus is to be used for the determination of the absolute values of the magnetic quantities, it is necessary to apply a correction to the readings. Since the apparatus gives consistent results on repetition, the whole error may be charged to errors in the correction or shearing curves. As this shearing curve varies with the dimensions and quality of the specimen, it is essential that shearing curves be prepared for each size and quality of specimen to be tested. With extreme care and the use of proper shearing curves, the apparatus is capable of giving quantitive results within 5 per cent of the true value of the magnetizing force for a given induction.

Uncorrected hysteresis data for hard steels show values of the residual induction that are too small; the error may be as great as 10 per cent. Values obtained of the coercive force are systematically too large; the error may be as much as 40 per cent.

* A brief summary of Bulletin 228, issued by the Bureau of Standards, describing an investigation made by Charles W. Burrows, Associate Physicist.

[1] L. T. Robinson: "A Modified Instrument for the Determination of B-H Curves," *Electrical World*, 23, p. 236, February 24th, 1894.

[2] A. Koepsel: Apparat zur Bestimmung der magnetischen Eigenschaften des Eisens in absoluten Maas und director Ablesung, E T Z, 15 p. 214, April 12th, 1894.

[3] H. Kath: E T Z, 19, pp. 411-415, 1898.

[4] E. Orlich: E T Z., 19, pp. 291-294, 1898.

[5] W. Rohr: E T Z., 19, p. 713, 1898.

Petroleum Conditions in Russia

THE report of the United States Geological Survey on the Production of Petroleum in 1913 contains the following statement:

The declining condition of the older Russian petroleum localities noted in the previous reports of this series continued in 1913. It was not compensated by increase in the new districts, which include Emba for the first time as a commercial factor. The outlook for the future of Russian production is brightened by the prospecting which has progressed rapidly in the Ural-Caspian region, north of Gurief. The field is reached by steamers to the north shore of the Caspian Sea. About thirty miles from the shore large wells have already been obtained at Dossor, and pipe lines are laid to Gurief, where barges can be loaded and then towed up the Volga without the reloading which is necessary with shipments from Baku. Oil from Baku destined for the Volga River trade arrives at Astrakhan in steamers too deep for the river and is then transferred to barges. Exploration in this Ural-Caspian field has been extended many miles north of the present developments. Prospecting is impracticable in winter, but in summer it can be prosecuted with success in spite of the lack of water, the available supply of which is derived principally from snow scraped up in winter and stored in pits. The inhabitants of the region are nomads living in tents. They are peaceful and disposed to aid exploration.

The Economies of Home Lighting

Facts and Figures on Various Systems, Past and Present

By Reginald Trautschold

EVERYBODY is interested in lighting, for no matter how humble home may be, lighting of some description is necessary. The progress made in the art of artificial illumination is familiar in a general way to all, but it is very questionable whether many are familiar with the economic aspects of this progress. Is lighting being more efficiently—economically—performed than it was 50 years or more back? Have the economics of the subject kept pace with the gains in convenience and facilities, or have these advantages been secured only at increased cost of lighting?

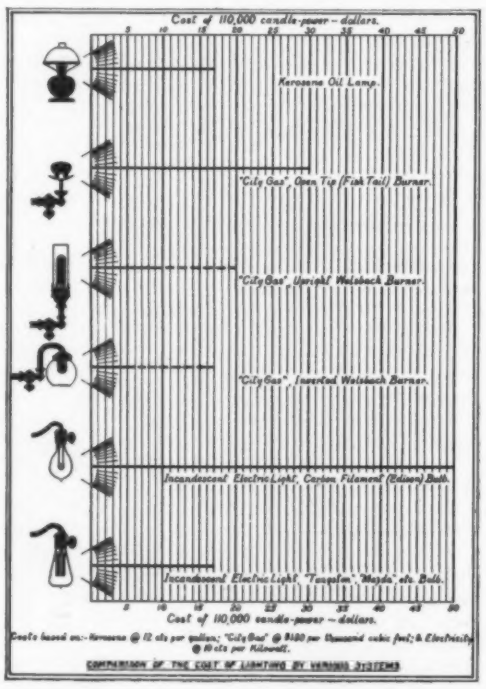
To arrive at a logical understanding of the efficiency of various systems of lighting a basis of comparison is necessary, calling for a unit of light measurement. The recognized unit is a candle-power per hour—not the ordinary candle that is procured at one's grocer, but an arbitrary unit, originally the light emitted by a spermaceti candle burning 120 grains per hour, known as the British standard candle, but later modified to the "International Candle" which emits slightly less light than the British candle. In the days when the kerosene oil lamp was about the best available source of light, the candle-power was not the term in which it was customary for the housekeeper to measure illumination, the measure in those days was far more apt to be the length of time that a five gallon can of oil would last. It was not until the advent of the electric light that the term candle-power came into general use. The 16 candle-power incandescent electric light bulb—the 16 candle-power Edison—then became the popular measure of comparison, but this, by the way, is far less reliable than the five gallon oil can measure, for a 16 candle-power electric light bulb does not emit 16 candle-power, rarely over 12 and frequently nearer 10. The five gallon oil can is capable of giving out 4,500 candle-power, if waste can be eliminated, and with any care at all the losses from a five gallon can should be very much less than 5 quarts, so that the five gallon oil measure for light is really more accurate and reliable than a measure based on the lighting capacity of an ordinary carbon filament electric bulb—the common type of electric light—taken at its rating. The housekeeper is now familiar with the term candle-power, but is almost as much in the dark as formerly as to its true meaning.

A candle-power is really such a small unit that a comparison of lighting costs based on it, though scientifically interesting, fails to impress any but the economist. Some concrete and larger unit presents facts so much more forcibly and clearly. For instance, the cost of lighting a small cottage or flat for a year forms a very much more understandable comparison. Taking the average year in and year out, such an establishment—if the hall light is turned down low, the kitchen light extinguished when the last dish of the day has been washed and put away and all the other little economies that are insisted upon by the careful housekeeper—would burn an equivalent of about 100 candle-power 3 hours each day, or 110,000 candle-power during the year, illumination that would not be very excessive for one fairly large room.

In the days of the kerosene lamp, the five gallon oil can would have to be replenished every two weeks or so, in such an establishment, for about 125 gallons of kerosene would be consumed during the year. Not to exceed this amount, the oil would have to be handled with great care—avoiding unnecessary waste—and the various lamps supplied at all times with clean clear glass chimneys and be devoid of all such light absorbing devices as shades. Such unattractive lamps would shock the artistic sense of even the most frugal householder, and the housekeeper would insist upon the use of shades for most, if not all, of the lamps, and this, even if discrimination was used to employ only fairly transparent shades, would mean about two more fillings of the five gallon can during the year. In days that have past, kerosene was cheaper than it is now, but if a fair comparison of the cost of lamp lighting is to be made with more modern lighting systems the average price of lamp oil to-day—about 12 cents per gallon—must be considered. If the original cost of the lamps be disregarded, the maintenance expenses for chimneys, wicks and so forth be overlooked, as well as that for the labor entailed in cleaning, refilling and caring for the lamps, the yearly cost of lamp lighting would be, if shades were not employed, about $15.00 a year, or, with shades, about $17.00. This latter figure may then be taken as about the yearly cost of kerosene lamp lighting for an establishment requiring 110,000 candle-power.

Ever since "city gas" first came into general use for lighting, the type of burner most commonly employed has been the ordinary open tip ("fish tail") burner, emitting a fan-like flame. Such a burner has a lighting capacity of about 20 candle-power, and to obtain 110,000 candle-power about 27,000 cubic feet of gas would have to be burned, or at least paid for, as there is bound to be a certain unavoidable leakage. This quantity would demand the use of unshaded lights only, for shades would, as in the case of oil lamps, lead to extra expense. Though shades are not deemed as necessary for gas as for oil lamps, some such extra expense, for the sake of "looks," would surely be incurred, so another 3,000 cubic feet of gas would be a conservative amount to add; and this would mean, at the average price of "city gas," about $1.00 per thousand cubic feet, a lighting bill of $30.

By substituting the more cleanly and convenient gas for oil lamps, the annual lighting charge would be very nearly doubled. The difference in cost of the two systems would go a long way toward paying for broken lamp chimneys, new wicks and to recompense the housekeeper for the extra work entailed in caring for the lamps. Civilization was not to be denied, however, so the housekeepers were finally prevailed upon to realize the wisdom of spending nearly twice the money they had been accustomed to spend for lighting for the privilege of evading some irksome and, it must be admitted, some disagreeable work.


Cost of 110,000 candle-power - dollars.
5 10 15 20 25 30 35 40 45 50
Kerosene Oil Lamp.
"City Gas", Open Tip (Fish Tail) Burner.
"City Gas", Upright Welsbach Burner.
"City Gas" Inverted Welsbach Burner.
Incandescent Electric Light, Carbon Filament (Edison) Bulb.
Incandescent Electric Light, "Tungsten", "Mazda", etc. Bulb.
0 10 15 20 25 30 35 40 45 50
Cost of 110,000 candle-power - dollars.
Costs based on:- Kerosene @ 12 cts per gallon; "City Gas" @ $1.00 per thousand cubic feet; & Electricity @ 10 cts per Kilowatt.
COMPARISON OF THE COST OF LIGHTING BY VARIOUS SYSTEMS

Whether the thriftiness of some good housewives and their disinclination to abandon the more economical system of lighting for the more convenient was the cause, or natural progress, it was not very long before the Welsbach burner was developed. The first of these burners, and that still most generally encountered, was of the upright type, consisting of a mantel of such fragile material, unfortunately, that a protecting chimney is necessary. This burner is very much more economical in the consumption of gas than the open tip burner for the same illumination, consuming only about one-third as much gas. The annual cost of illumination—110,000 candle-power—would then be, with "city gas" at $1.00 per thousand cubic feet, about $10.00, less than two-thirds as much as that of oil lamp lighting. Unfortunately, the full benefits of this system of lighting have never been realized and probably never will be. The full value of light is not properly comprehended and the temptation of using more light and still more is too great for the majority to resist, particularly when little or no more effort is necessary to secure it and the extravagance only becomes apparent when the light bill is presented for payment. When the light bill is smaller than it was formerly—open tip burners probably having preceded the Welsbachs—it is still more difficult to realize that economy in the use of light has not been what it should. In an establishment where Welsbachs can be used, provision is also adequate for open gas tip burners, so that if the same economy is to be observed in the use of light, only the equivalent of one-third as many Welsbachs should be used as open tip burners. For economy, only certain burners in the establishment should be generally used and the use of all others prohibited; but always some of these forbidden burners are so conveniently located that the good resolutions are not kept. Still another reason for failure to realize the full economies of the Welsbach is that the mantels are fragile and liable to destruction and the chimneys will break or crack; so that unless a supply of extra mantels and chimneys is kept on hand, a temporary return to the open tip burners becomes necessary, with the accompanying consumption of three times the amount of gas, if the same degree of illumination is to be secured. The lighting bill when employing upright Welsbachs is, therefore, very much more likely to be about $20.00 than $10.00. Even at $20.00 per year, the saving of the Welsbach system would mean the cutting down of the gas bill for open tip burners to two-thirds, less than 20 per cent more expensive than lighting by lamp.

The upright Welsbach is not the most sparing in the use of gas, however. The inverted Welsbach mantel being even more economical, due to the more efficient mixing of gas and air before it is ignited. This type of burner consumes but about one-fifth as much gas as does the open tip burner, so that, if its full economic value could be realized, the expense for 110,000 candle-power would be but $6.00. The same drawbacks that prevent the realization of the full value of the upright Welsbach apply with equal force to the more efficient inverted burner, so that it is doubtful if their use would cut the annual gas bill much below $16.00 or $17.00. At such rate, all the benefits and advantages of gas lighting may be gained and many of the disadvantages of the oil lamp evaded, with a lighting bill no greater than that required for the use of oil lamps.

Disadvantages that are possessed by gas lighting as well as by kerosene lamps are that matches or other means of ignition are required; while giving out light they also give out considerable heat; and they consume much of the oxygen of the air while burning, a decided disadvantage in the present hygienic age. These disadvantages have made possible the great inroads of electricity into the domain of lighting. For domestic purposes the incandescent electric bulb is almost universally used, and, until recent years, this meant the common carbon filament lamp—the Edison lamp. These lamps are made in various sizes, capable of emitting a definite amount of light—the usual *rated* candle-power being 16 and multiples of 16. The average consumption of electrical energy by such lamps, with clear glass bulbs, is very close to four and one-third watts for each *actual* candle-power, so that for 110,000 candle-power about 475 kilowatts (1 kilowatt = 1,000 watts) would be required. As some shades or frosted bulbs would very probably be used in any private apartment or house, a more conservative figure would be 500 kilowatts. At 10 cents per kilowatt—the average rate charged by electric light companies for such small amounts of current—this would make a lighting bill of about $50.00 a year, 66 2/3 per cent more expensive than gas lighting with open tip burners and nearly three times as expensive as lighting by kerosene lamps. Decided advantages are realized by such a system of lighting, it is true, but only at the cost of considerable expense.

In the last few years there have been put on the market several electric light bulbs that are very much more economical in the consumption of electricity than the carbon filament bulbs—bulbs in which the carbon filament is replaced by fine wires of a metal that becomes incandescent more easily than the carbon filament. These bulbs, known under various trade names, such as "Tungsten" and "Mazda," consume but about one and one-third watts for each *actual* candle-power, instead of nearly four and one-third as do the carbon filament bulbs. Naturally, these more efficient bulbs greatly reduce the cost of electric lighting, so that by their use the lighting bill for 110,000 candle-power is reduced to from $50.00 to $17.50, very close to the amount that would be required for securing the same amount of light from oil lamps. This is about the latest thing in the way of electric lighting and at the present time cannot be very much bettered unless the price of electricity can be brought below 10 cents per kilowatt.

It is curious to note that each advance in the art of lighting, introduction of a more convenient and it may be assumed more efficient system, has created a very material increase in the cost of lighting, as heavy payment was demanded for each added convenience; and progress and improvement in the various lighting systems have as yet been unable to better the cost of lighting under the old kerosene oil lamp system. What future progress will

bring about is difficult to say, but it will in all probabilities be a marked reduction in the cost of electric lighting, the conveniences, safety and hygienic advantages of which system makes it superior to all others.

It is a well known and generally admitted fact, that it would be quite possible to use "city gas," at its present price, in a gas engine by which a lighting dynamo could be driven and supply current well under half the price now being charged for electricity by the large public service companies. Such practice would be entirely out of the question for each individual habitation, or any but a large establishment, on account of the comparatively high cost of initial installation and the impossibility of securing the necessary attendance at any price commensurate with the value of the electrical output. Such a scheme would be quite feasible, however, for a group of consumers or a community in which the demand for light was fairly uniform and constant, but even under such favorable conditions the experiment would hardly be a wise one, as still more economical results could be obtained through the use of oil engines in place of a gas engine operating on "city gas."

At the present price of kerosene, the fuel expense for an oil engine using such power medium would be but about 2 cents per kilowatt electrical output, or, if crude or fuel oil was used, this would be cut down to 1 cent, or less, for each kilowatt delivered by the electric light dynamo. Electric light rates commensurate with such fuel expenses could only be realized in cases where the demands for current were pretty uniform and constant during certain fixed hours of the day and no current required during the balance of the twenty-four—the reason that the public service companies find it necessary to charge such an apparently exorbitant rate as 10 cents per kilowatt. This will necessitate comparatively small communal lighting plants operated on a co-operative basis, for only by such means can the true economy of the efficient, convenient and altogether desirable electric light be furnished to the public at a price anywhere near that which the cost of production should command.

The future source of light may again be from the "oil can," but instead of burning the oil, as in the old days, the more efficient method of exploding it in an engine will be resorted to.

Science and the Tariff

Delicate Apparatus Employed in Determining Customs Duties

By Dr. E. E. Pickrell

But few people are aware that science is a valuable assistant to "Uncle Sam" in the enforcement of the tariff laws in ascertaining the duties on imported merchandise, and that the application of every new tariff is more dependent on science. How many persons realize, when they purchase an article made wholly, or in part, of imported cotton yarn, or cloth, that the United States Government, in collecting the duties on that article, took into consideration the fact that cotton yarn and cloth are hygroscopic, and the amount of moisture they contain is dependent upon the temperature and relative humidity of the atmosphere? But few have a knowledge that in the administration of the cotton schedule of the tariff act of October 3d, 1913, the U. S. Treasury Department has taken into consideration the moisture content of cotton yarn and fabric. Schedule I (otherwise known as the cotton schedule) of this act provides for cotton yarn and fabric at an *ad valorem* rate of duty and establishes the lines of demarkations of the various classifications, according to the yarn number.

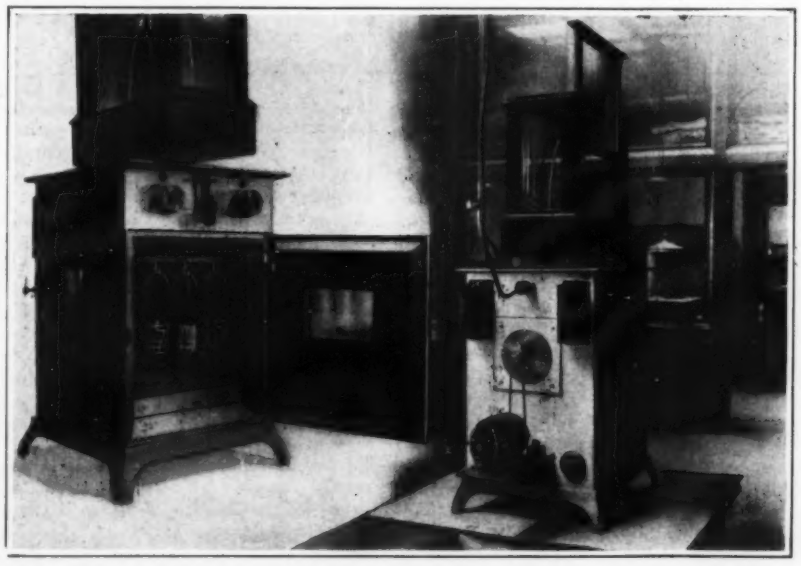
In the ascertainment of the yarn number the weight of the yarn, or cloth, is one of the principal factors. The moisture content, therefore, bears an important relation to the weight, and consequently to the yarn number. The quantity of moisture cotton cloth or yarn contains depends upon the temperature and relative humidity of the atmosphere. As an illustration, let us take a sample of 840 yards of cotton yarn, which under atmospheric conditions of 70 deg. Fahr. temperature and 65 per cent relative humidity, weighs 116.67 grains. The yarn number of this sample is 60, for a No. 1 cotton yarn is a yarn 840 yards of which, under these atmospheric conditions, weighs 1 pound, or 7,000 grains, and a No. 60 cotton yarn weighs 1/60 of 7,000 grains, or 116.67 grains. In this sample the proportion of moisture to dry cotton is as 8½ parts to 100 parts, or 9.14 grains to 107.53 grains.

Expose this sample for a sufficient period of time to an atmosphere of 73 deg. Fahr. and 46 per cent relative humidity, and it would weigh 114.19 grains. Its yarn number would be 7,000 divided by 114.19, or 61.3. The moisture content would be 114.19—107.53, or 6.66 grains, representing 6.19 per cent of the dry cotton. Place the same sample in an atmosphere where the thermometer reads 68 deg. Fahr. and the hygrometer records 97 per cent, and its weight would be increased by 121.95 grains, which is equivalent to a yarn number of 57.4. The moisture content would be 121.95—107.53, or 14.42 grains, which represented in percentage of the dry cotton contained in the sample, is 13.41. It is therefore, quite apparent that a few degress in temperature and a variation in the relative humidity has an appreciable effect upon the weight of cotton yarn, and yarn number.

If, on the day of importation of a consignment of cotton yarn into the port of New York, the thermometer registered 73 degrees and the hygrometer returned a reading of 46 per cent, its yarn number, as ascertained, would be 61.3, and the merchandise, accordingly, classified under paragraph 250 of the tariff act as cotton yarn exceeding 59s to 79s at 22½ per cent *ad valorem*. But, provided the temperature and humidity had been 68 degrees and 97 per cent, respectively, the yarn number would necessarily have been 57.4, and in the classification of the importation, a rate of duty of 20 per cent *ad valorem* would have been assessed as for cotton yarn exceeding 49s to 59s. To avoid these differences of classification and assessment of customs duties on cotton yarn and cloth, due to variations in the atmospheric conditions, the Treasury Department has declared that "whenever the weight is found within 5 per cent of its given equivalent weight in the table it will be necessary to make further trials of at least four samples, and if the average weight is again found to be under 5 per cent, the sample must be conditioned; that is, dried to bone dryness, and a regain of 8½ per cent added back."

Bone dryness of the cotton yarn, or cloth, is a condition in which all moisture is expelled, and this is only accomplished by dryness to a constant weight in a circulating atmosphere at a temperature of 110 deg. Cent. The regain of 8½ per cent added to the bone-dry weight would give the weight of the cotton yarn, or cloth, as if it had been subjected to an atmospheric condition of 70 deg. Fahr. temperature and 65 per cent humidity.

In order to determine accurately the bone-dry weight, the Treasury Department has recently installed in the United States Customs Laboratory, Appraiser's Warehouse, 641 Washington Street, New York, a type of a machine known as the Freas electric-conditioning oven.



The oven has a one-fifteenth horse-power motor connected by a belt with the fan which maintains a circulating atmosphere within the oven.

The oven is built of heavy fireproof asbestos wool, with chamber size 12 inches by 12 inches by 12 inches. Two small electric lights are placed in the upper inside corners of the chamber, and can be turned on or off by a switch-button on the front of the oven above the door. One of the lights is continuous, and serves as a source of illumination for the oven, and the other is intermittent, and indicates the making and breaking of the contact of the heat regulator.

To expedite the drying, the circulation of heated air supplied to the oven is artificially adjusted by means of a fan situated in the back of the chamber, and driven by a 1/15 horse-power motor, shunt wound, with a speed of 1,100, and a voltage of 110. Complete ventilation, to get rid of the moisture from the substance being dried, is obtained by two openings, or vents, one on each side of the back of the oven next to the bottom; these openings can be closed, or partially closed, by means of metal plates which fit over the openings, and are readily turned.

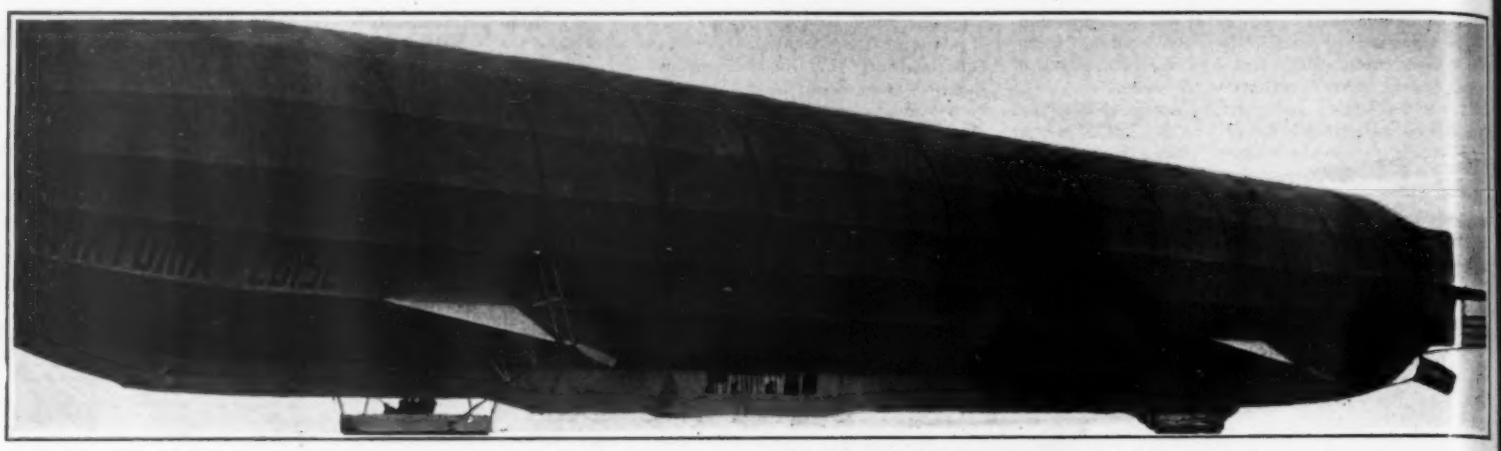
The heating element, which is wound with a high heat-resisting wire, is situated in the bottom of the chamber underneath a fire-clay plate which contains numerous holes for transmission of heat. The regulation device is fitted in a separate compartment made entirely of metal, and located above the chamber. Its action depends on the expansion of the metal tube through the chamber, operating a lever, which makes and breaks a contact, with proper means to prevent arcing. The lever is extended to serve as an indicator, operating up and down a graduated scale on the outside of the oven. The indicator is moved to the desired temperature by simply turning the knob screw at the bottom of the scale.

The oven is also provided with a double window (mica on inside and glass on outside), with drop shield, on the side of the oven, so as to permit operator to manipulate the horizontal rod with fastened hook for removing and returning baskets from carrier to connecting rod attached to one arm of the balance.

To the top of the chamber is fastened a four-armed horizontal metal frame. At the end of each arm is attached a small pulley, and on these pulleys moves an endless chain, similar to a bicycle chain. This chain is moved by a toothed wheel on the side of the chamber, which, in turn, is moved by a thumb-screw on the outside of the oven. Ten metal hooks are suspended from the chain, and to these are swung ten metal mesh baskets, each of which is 6 centimeters in depth by 4 centimeters in diameter. By the aid of the thumb-screw, the carrier can be turned, so as to bring the baskets into position under the balance to be weighed within the oven.

On top of the oven is an analytical balance of 100 grammes capacity and 1/10 milligramme sensibility, one arm of which is attached to a connecting rod which passes through an orifice into the oven. By turning the horizontal rod which traverses the rear of the chamber, the baskets can be removed from the carrier and attached to the connecting rod which passes into the balance. By moving the carrier the baskets can consecutively be brought into position and attached to the connecting rod. All the baskets are adjusted so that they weigh the same, and are equal to the counterpoise which is suspended from the other arm of the balance.

In the conditioning of the samples of yarns and fabrics weighing 1,000 grains and less, this oven possesses the following features that are superior to other conditioning ovens, both electric and gas, that are now used in the textile trade: (1) It occupies a small space, about three feet square; (2) a constant temperature within 1 deg. Cent. scale can be maintained; (3) ten samples can be conditioned at one time; (4) an analytical balance with a maximum load of 100 grammes and 1/10 milligramme sensibility can be used for weighing the samples within the oven.



The "Viktoria Luise" was formerly a Zeppelin passenger airship, but is now a war craft attached to the German navy, known as "LZ-II." She was completed in 1912, is 483 feet long, with a gas capacity of 664,000 cubic feet.

The forward car carries propelling engines, the pilot, and observers. The rear car also carries propelling engines and engines for supplying electric lighting. These cars are connected by a gangway with the central cabin, which has a considerable carrying capacity. These vessels usually travel at a height of 8,000 feet, to avoid anti-aircraft guns. The greatest height reached by a Zeppelin is 10,400 feet, and it required an hour to reach that elevation.

An Airship in the Field*

A Personal Narrative from a German Observer

"Up to now the airship branch of the [German] military service has been particularly silent concerning its doings, but there is no doubt that it will perform a tremendous work against the enemy. There is good ground for belief in the effectiveness of this weapon, in which—even our enemies acknowledge it—German energy and thoroughness have surpassed all opponents. Although England and Russia completely, and the French in a slightly lesser form, denied the utility of these air-cruisers, claiming that they could easily be put out of action, yet to-day they undoubtedly sail over the lines and fortresses of the enemy. In spite of their size and the slowness of their flight they are less vulnerable than the aeroplanes, because even many hits and the loss of several people does not essentially damage the great airship unless under exceptional circumstances.

"The account of a long journey was related by a German airship officer to an Austrian reporter at the time of the first great battle on Polish ground. 'We were 13 hours on the way, doing 700 kilometers, of which 500 kilometers was over the enemy's country. It was still dark when my man woke me in the morning. In an hour's time we had sighted B——, while 2 hours later we crossed the frontier. We went at 2,000 meters. Czenstochowo lay outlined below us; the Warta twisted in its marshy course among the hills. For 100 kilometers we followed the railway to Kielce, and saw soldiers marching along half of the distance under us who were either Russians or Austrians. We threw down friendly greetings and turned to the north-east, the railway showing us the way. The forts of Ivangorod lay like small four-cornered cubes round the fortress; we turned away from them. The heights of Radom were crowded with soldiers. It was obvious that the Russians were in strong force and were prepared to receive the enemy.

" 'Our appearance created huge excitement among the great gray patches below, which were the regiments; thousands of white gunpowder smoke came puffing, only visible by the telescope. Near Lublin there was firing from large masses of troops, who covered the whole level plain to the horizon. South-east of Lublin infantry was forming, quite visible though small, with artillery in front. The smoke from the cannon rolled itself into a ball, and for the first time we heard through the noise of our own motor the detonation, though very faint and far off. I was in the back gondola; it sounded like the rapping of one's knuckles against a wall. Then, again, right under my feet, the bullets hit but recoiled harmlessly from the metal covering of the gondola. Then a bullet went by my ear, into the outer covering of the balloon which hung over our heads like a gigantic silver roof, bored a tiny hole in it, ripped a strip of the inner lining, and lost itself in the hydrogen.

" 'Bullet now followed fast on bullet; we counted twenty-five hits, twenty-five holes through which the gas escaped, also the shells came nearer, a splinter fell in our gondola like a stone. A telegraph message came from the front gondola, "Full speed!" All four motors drove. Then came the order to patch what needed patching. Swinging between heaven and earth we repaired what was possible to repair. As the sun was sinking we landed among the vanguard of our friends, gave our report, journeyed on again, and ended in the Austrian headquarters.'

"So much for the information-gathering journey. Originally the idea had been to cause destruction to fortified places, but now it has also been found possible to be useful against the armies in the field. As to its effect on towns, we know a great deal from actual witnesses in the bombarded towns. Liege, Namur, and Antwerp were the first towns to make acquaintance with the fear of the air, and undoubtedly the moral impression of these visits hastened the surrender of all these towns."

A citizen of Antwerp relates the following: "I was awakened at 1 o'clock by the tremendous humming of a motor. It came from above. I opened the window and saw to the south over the railway station a gigantic being, which threw a stream of light on the town. Then followed a noise like muffled bells and a clap of thunder. Again a stream of light, and two seconds later a sound as if two goods wagons had crashed against one another with terrific force. Then followed, thundering from the guns of the forts, rifle-fire, and between them the bombs of the German airships. The inhabitants all streamed into the streets, men, women, and children, in their night clothes, wandering from one corner to another, seeking safety, for at first the people thought the bombardment of the city had begun.

"That was the beginning. Since then the methods and the weapons of the airships have been necessarily perfected till the early work seems mere child's play compared with the destructive power of the present weapons. For example, at the visit over Ostend, while it was still in the hands of the English, the projectiles produced frightful destruction. 'It was,' so writes the Antwerp *Metropole*, 'a quarter to twelve at night, while Ostend lay in the deepest darkness, that a telephonic message from Thourout informed the commandant that a Zeppelin was passing in the direction of Ostend, and a few minutes later one could hear the fearful hum of its engines, 200 meters above the roofs.' (The witness was deceived over the real flying height of the airship, but the night is naturally not good for such observations.)

"The Zeppelin turned its searchlight on the sea coast, then took the direction of the railway station, and soon four fearful detonations tore the stillness of the night. The citizen guard of Ghent, who were occupying the station, fired twice with the guns, but with the swiftness of the wind the airship disappeared into the night. The first bomb had torn a hole in the Bois de Boulogne more than 32 feet in circumference and 16 feet deep. The others had produced 'fantastic destruction' near the station, but had not actually hit it. Fitted out with more machine guns the Zeppelins are also unpleasant opponents for the troops."

*This narrative and the accompanying illustrations are derived from *The Sphere*, London.

Damascus Blades*

As just now weapons of all sorts have more interest than usual for most of us, perhaps the following, which appeared a good many years ago as an appendix to Captain Abbot's journey to Khiva, may be of service. It was a translation by Captain Abbot of a paper written by Colonel Anossof, a well-known manufacturer at Zlatoost, in Siberia, and as it deals entirely with an art of the past, is not at all out of date.

In Russia we understand by the damask, a metal harder, and supplying a material for arms of keener edge than ordinary steel.

The original country of the damask is the East, and there is reason to think that its properties were even less understood in other countries of Europe than in Russia.

All the researches of chemists have, until now, failed of discovering any essential difference between the damask and ordinary steel, which, nevertheless, proves only that the analysis has been imperfect. Although the chemists of the present day presume that the natural damask is the effect of a crystallization, produced by retarded cooling of the heated metal; yet, not having the means of producing a damask equal to the ancient work of Asia, they cannot establish this ground; although they have before their eyes the laws of crystallization discovered by the mineralogist Haüy.

If crystallization generally is but the result of the structure of bodies, under certain physical considerations, the question follows, wherefore in the damask is it not the result of a similar cause; and as common steel acquires no visible damask by artificial refrigeration, is not this a convincing proof that the composition of damask differs from that of ordinary steel? If chemical analysis fails to discover that difference, we can only conclude that it answers not its end. The researches of metallurgists and of artificers, who have been at pains to make the damasks, and to inform themselves of the ancient art, have made no decisive progress. I have seen no damask of superior quality wrought in Europe; and that which has been written upon the subject gives no sufficient light; for I have found in no treatise upon the damask any provision for perfecting the steel. Thus, on one hand, the imperfection of our chemical knowledge, and on the other, the difficulty of fabricating the damask, leave Europeans still in uncertainty as to its merits. Many scientific men, relying upon chemical analysis, refuse credence to the superior qualities of the damask; while amateurs, who have any knowledge of the subject, set as great value upon it as do the people of the East, and willingly pay £50 and upwards for the best damask blade.

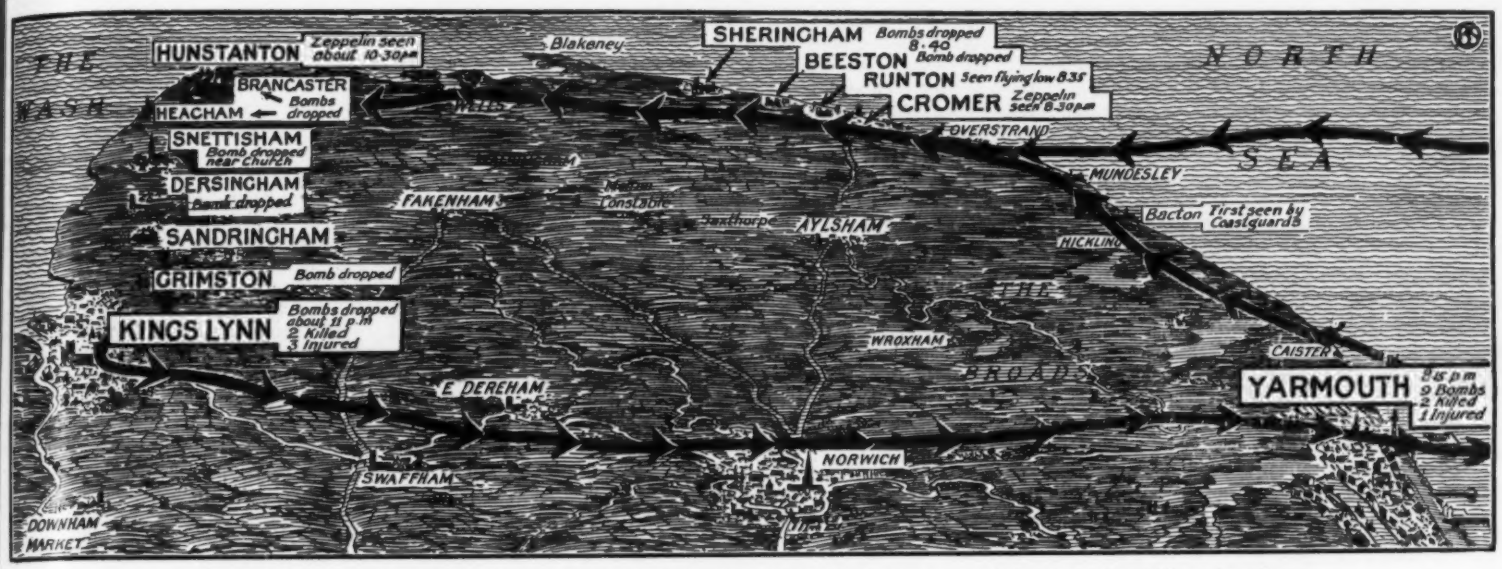
Time out of mind the damask has been used in Asia; and to this day it has lost nothing in price. Nevertheless, the Orientals, although less advanced in knowledge than ourselves, could not be deceived throughout the course of ages, upon the merits of objects purchased only at a very high price.

All steel which exhibits a surface figured with dark lines is called damask.

In some of the various kinds of steel these figures appear immediately after burnishing; while in others dilute acid is necessary to bring them out. The juices of plants and ordinary vinegar suffice for this effect. The process of bringing out the figures of steel is called corrosion.

The damascene which appears upon the surface of

*From the *English Mechanic*.



How the German air attack on the east coast of England was carried out—the course followed by the raiding aircraft.

It was, apparently, at Yarmouth where the first bombs were dropped at 8:15 P. M. on the night of the German raid. After passing Yarmouth the aircraft appeared to visit many coast towns in succession. At Beeston, Sheringham, and Heacham bombs were dropped, as also at Brancaster. At Snettisham a bomb was dropped quite near to the church. The last town on which bombs were dropped was King's Lynn, whence the aircraft proceeded in an easterly direction, passing across Yarmouth once again and making direct for the North Sea and German territory.

steel is very various; nevertheless, this damascene does not alone confer upon steel the title of damask; on ordinary steel, similar figures may be brought out by subjecting it to corrosion, after having designed upon it the figures required; but whatever pains may be taken to make such resemble genuine damask, the eye of a connoisseur easily detects the counterfeit without examining the quality of the metal. Hence has arisen the epithet of "false damask."

A second kind of damask exhibits also an artificial damascene, which, nevertheless, is peculiar to the metal itself, so that, how oftensoever it is repolished, the same figure will reappear whenever it is subjected to corrosion. This damask is known as "artificial damask." It is composed of several sorts of steel interlaid with iron. The beauty of such damask is various, and consists partly in the quality of the several materials, partly in the skill with which they are worked together. These artificial damasks are chiefly wrought in Asia—viz., India, Turkey, Georgia; but the artificial damasks of Europe have attained as yet no great reputation, because the European workmen are more intent upon producing elegant figures on the steel than in improving the metal itself. Thus the artificial damasks, as those of Solinger and Klingenthal, although exhibiting the damascene, have not the figures characteristic of superior metal.

In fine, whatever may be the beauty of artificial damasks, they will not bear comparison with good natural damasks, for, if filed, the damascene does not reappear.

The natural damasks of Asia differ from the artificial in the reappearance of their inimitable and (so to speak) innate damascene, as well as by the faculty of reproducing the same damascene after having been filed, if the constituent particles remain unchanged.

In Asia we observe many kinds of damask. The difference between them depends upon the places in which they have been wrought, the manner of their fabric, and the various qualities of the material. Those most in use are known by the names of Daban, Kara Daban, Khoroussaun, Kara Khoroussaun, Gundy, Koum Gundy, Neuris, and Schaum (Syria).

The Orientals judge of the goodness of the damask by its figures, by the color of the ground (that is, the intervals between the figured lines), and by the play of colors. They consider the Daban and Khoroussaun (to the latter they sometimes add Kara or black) to be the best blades. The Schaum is the least esteemed. The constant experience of many years assures me that the marks upon which the Orientals found their judgment of the goodness of the damask are a more certain criterion of the true quality of the metal than all the tests to which it is subjected in Europe.

As above stated, the first and most essential sign of the damask is its damascene. In proportion as it is thick, defined, fantastic, in the same proportion is the quality of the metal fine. The thickest damascene is about the size of the notes of music, the middling as large as ordinary print, and the finest is that which we can just follow with the naked eye. As to the method of recognizing the quality of damask by its figures, and to the reappearance of the damascene, although they depend upon invariable laws, it were easier to give an idea by samples than by simple description. Nevertheless, it may not be useless here to add certain directions upon the subject, which are not founded upon practice alone, but proved by the process I employ in the fabric of damask.

Like written characters, the damascene consists of points, of right lines, and curves, which serve to distinguish the quality of the damask, as follows:

1. The damascene formed principally of right lines, almost parallel, denotes the lowest quality of the damask.

2. When the right lines become shorter, and are partly replaced by curves, they denote a better quality than the first.

3. When the lines are interrupted, show points, and when the dimensions of the curves increase, this is still a better symptom.

4. When the interrupted lines become still shorter, or rather, when they change to points, as they increase in number, so as to form in the breadth of the steel here and there, as it were, nets, interlinked by threads which undulate in diverse directions from one net to the other. In this case the damask approaches perfection.

Finally, when the nets open farther to form figures resembling grapes, or when they occupy the entire breadth of the steel, and partake it in nearly equal articulations, in that case the damask may be recognized as of the highest possible quality.

Another feature by which the quality of damask may be understood is the hue of its ground. The deeper the tint, the more perfect the metal. The ground of the damask may be gray, brown, or black.

A third feature is the play of colors upon the metal, when its surface is subjected to an oblique light. In observing many thus, we perceive that some among them show no variation of tint, while others take a crimson or a golden hue. The more perceptible this play of colors, the finer the quality of the damask. Nevertheless, this test is affected by the degree of corrosion. When the corrosion is very great the play of color is not observed. No art can produce the red hue upon inferior damask. Therefore, the damask may be divided into two distinct classes—viz., that which has the red hue, and that which wants it.

When the three characters above noted are found in union and at their maximum, we may confidently pronounce the damask to be of the most perfect kind, which will in no case fail of the following qualities:

Perfect malleability and ductility. The hardest possible substance after tempering. The keenest and firmest possible edge. And elasticity, when properly tempered.

The other damasks possess various degrees of perfection, according to the three above-named qualities are more or less remarkable.

Among damasks of inferior quality may be found some inferior to cast steel of medium quality; but it is not known that the best cast steel may compare with the finest damask. Comparative proofs have convinced me that the damask offers the highest possible perfection of steel, and the relations we receive from those who have visited Japan, the Indies, Persia, and Turkey are not so exaggerated as many suppose. A well-tempered saber of good damask will easily sever bones, iron nails, and the most flimsy kerchief as it floats in the air. But I must beg leave to doubt the possibility of performing similar feats with similar ease with European blades, such as those of Kligenthal, as we are assured in a late publication; for I am persuaded that the blades of Kligenthal, of Solingen, as well as those of Zlatooste, of similar temper to good damask, cannot be compared with the latter, whether in edge, in solidity, or in elasticity.

The employment of damask might, I think, be extended with advantage not only to the fabric of arms, but in general to every steel article requiring edge or solidity.

NOTE BY CAPT. ABBOT.

So far Col. Anossoff, a man whose researches in this department of science have enabled him to revive the natural damask in a degree of perfection which I have never observed in the workmanship even of the ancients, and which certainly cannot be approached by fabrics of any Eastern nation at present existing.

This, it will be allowed, is very high authority; the more especially as the Russian collections exhibit probably a greater variety of damasks than those of any other European nation. And to differ in any point with such an authority may not only seem presumptuous, but may absolutely insure the rejection of my opinions as futile. Nevertheless, as I have taken upon me to reprint his valuable remarks in a work of my own, it seems incumbent upon me to add to them some of the results of my own experience.

The blade known in Khorussaun as *the* Khorussaunie blade has a very dark hue, betraying a steel highly carbonized. The figures of its damascene are very curious, and I despair of giving any distinct idea of them without the aid of plates.

1. The kind least esteemed is a light gray, having a granulated surface, the spots of which are rather long in the course of the metal. This kind is also forged at Lahore and Siroce.

2. The second kind has a figuring of coarse dark lines upon a gray ground, these lines exhibiting figures almost precisely similar to the grain of a young oak, when the oblique section has passed near the center of the tree.

3. A third has the same gray ground and dark, irregular lines; but these are more continuous, and not disposed in concentric figures, but have rather the appearance of tissues of wire, running into every serpentine shape.

4. A fourth is a repetition of the last, but the lines are finer, and the figures more uniform in their irregularity, forming homogeneous masses, so to speak. This is the kind most highly esteemed by the people of Khorussaun. It varies greatly in beauty and valve, and may be purchased at from £5 to £500.

5. A fifth kind exhibits a series of articulations, of which I have counted thirty-six in a sword-blade. These articulations, or knots, are formed by dense masses of nearly parallel lines, disposed lengthwise in the blade; the masses running into one another. At the junction they are excessively fine. On turning the blade, it will be found that each junction on the one side corresponds with the center of a mass on the other; a proof that the blade had been formed of two distinct laminæ welded together, and a strong presumption that the articulations are artificial, and that the junc-

tions are considered by the workman as the weak points of the steel. This is certainly the most beautiful variety of Khorussaunie blade; but I have not observed that it is so highly esteemed as the finer kinds of the foregoing variety. It varies greatly in quality, the finest lines denoting that which is considered best.

All these blades, when attentively scrutinized, will be found to possess a seam down the back, betraying the welding of the double plate of which they are composed. None of them possess any elasticity. They will either break short, like cast iron, or bend like lead. I have never observed in the finer kinds any superiority in edge over the elastic blade of Germany; but the inferior kind, being often more highly tempered, are keener and very brittle. Their shape is a simple and often abrupt wedge, the very worst shapes for cutting, owing to the great friction which the lips of the wound exert upon the sides. Their figure is too crooked for defense. They are not esteemed unless a cat can walk under the curve when placed edge upwards on the earth; neither is this degree of curve sufficient to confer great value, unless it be elegant in its gradations. The edge is generally obtuse, and seems formed rather to bear the shock with armor and with other blades, than to cut deep. The breadth is seldom great, but they are thick at the back, and always ill-poised. The best are from Isfahaun; but I understand that the art is almost lost, even there. The best I have ever seen I bore as a present from the King of Khaurism to the Emperor of Russia. Its ground was a grayish azure, in which the lines were most delicately traced in somewhat darker dye. It was not articulated. The back had a coarse seam throughout its extent, which had been so imperfectly welded that the blows of the Kuzzauk clubs opened it. This seam is, I think, invariable in the finer Ishfahaunie blades. I believe the object of it is to be twofold. In the first place, to have as large a surface as possible purified by the action of the hammer; and, secondly, by doubling back the plate, to secure an edge free from wiry particles. The blade in question had very little elasticity. I have never seen a Khorussaunie saber pointed with a double edge. It is true that the blade is too crooked to be used in thrusting; yet I have seen Damascus blades equally crooked, that had the double-edged point.

The daggers of Khorussaun are somewhat different in water or damascene from the sabers of that country; greater care seems to have been taken in the process. The lines upon them run into the most delicate and perfect spirals and minute curves. Their appearance, I should say, offers abundant evidence of their being forged of mixed metals; probably they are bundles of wires, of spiral forms, welded together in a mass. They are generally of the most elegant figures, seldom double-edged, probably from the superstition against this figure prevalent at Khiva, where the double-edged dagger is religiously disused, because Hosein, the son of Ali, was slain with a double-edged knife. The point is generally triangular and tapering, serving well to force the links of chain armor, which was once commoner than at present. They have, however, a double-edged dagger called Khunja, which is worn in Persia, although the people being Sheeahs, are so much more interested in the fate of Hussun and Hosein.

One of the peculiarities observable in all good Khorussaunie blades is that toward the edge the hue of the steel increases in depth, betraying more strongly the presence of carbon; a fact which proves that a mixture of metals was employed in this species of damask, the harder disposed toward the edge of the blade, the less brittle at the back, with the view to combine the greatest keenness of edge with tenacity to resist concussions.

In Col. Anossoff's Oriental nomenclature occur several names unknown, I think, in Khorussaun and India; for instance, Daban Gundy and Neuris. Upon these I can, of course, offer no remarks. But with respect to the blade of Schaum, I know not how the Tartars dwelling in Russia may apply the epithet, but its real and original meaning is the blade of Damascus; a city which has given name to all steel fabrics exhibiting upon their surface what is termed water. It is true that the art of damascening seems in the present day to be lost at Damascus, and the blades forged in Syria may, therefore, deserve the contemptuous estimate which the Tartars of Russia seem to entertain for them. But there can be little doubt that of all watered blades the Damascus blade was the most perfect, and the only blade of this description, anciently forged, that had any elasticity. I confess I have never met with an elastic Damascus blade; but there seems to be sufficient evidence that the ancient fabric was elastic. We read an absurd account of a Damascus blade, appertaining to the celebrated Kaliph Haroon ool Rusheed, so elastic, that the monarch usually carried it coiled up like a watchspring in his turban, and travelers give frequent testimony to its elasticity. As few Asiatic swords are flexible, the idea could not have entered the mind of an Asiatic without some foundation in fact. And as European travelers would naturally, after the fashion of their people, test any sword brought for examination by bending it, they could scarcely have fallen into error as to the elasticity of these blades.

A blade that was in my possession, essentially different from those of Khorussaun and India in figure and texture, and wrought in Egypt, probably by Syrian workmen, exhibited the most exquisite water, and an edge that I have never seen equalled; but, although not brittle, it was unelastic. Its structure could scarcely be attributed to the natural arrangement of fiber of the steel in the process of crystallization. I have no doubt that the blade of Damascus was of this character, though probably in the present fabric iron has been substituted for soft steel, and thus the elasticity is lost.

It is to be observed that such blades are generally so massive as to render elasticity a matter of little moment, as they will not shiver in any concussion, and scarcely any force to which a saber is liable will materially impair their straightness. Their color is a very pale azure. The streaks are delicate, elegantly waved, and curved, much fainter than in the Khorussaun blades, and appear to be brought out without aid of acids, by the mere action of the atmosphere. Nothing that I have seen approaches in beauty to these blades, or in firmness and keenness of edge. The people of Khorussaun term them Misrie, that is, Egyptian, and believe that they will sever steel. The kingdoms of Egypt and Syria having for some time been under one rule, I have little doubt that whatever art of damascening remains in either land will at present be found at Alexandria and Cairo.

The streaked damask, spoken of in Col. Anossoff's memoir, I have not noticed, because I do not conceive it to deserve the title, being a wretched imitation of the Khorussaun blade.

The Russian damask, on the contrary, discovered by my friend Col. Anossoff, is natural. It is a peculiar modification of cast steel, by which it is impressed with a peculiar character in its crystallization. Which character betrays itself when the corrosion of acids, by acting more violently between the interstices of the structure than elsewhere, traces out the arrangement of the crystals. This property is communicated to the damask of Zlatoost by a process, tending to perfect the quality of the steel, and to impress upon cast steel the elastic properties of a softer material. The general fault of European blades is that being forged of shear steel for the sake of elasticity, they are scarcely susceptible of the keen edge which cast steel will assume. The genius of Anossoff has triumphed over this objection, not in hardening the soft steel, but in giving elasticity to the hard; and it may be doubted whether any fabric in the world can compete with that of Zlatoost in the production of weapons combining in an equal degree edge and elasticity. The water of this variety of damask resembles most that of No. 5 of my list above. It is a succession of small bundles of almost parallel lines, occupying the whole breadth of the blade, the ends of the bundles crossing and mingling at the point of junction. I have called them nearly parallel lines, because such they are to superficial observation. They are, however, a series of minute curves, forming together lines disposed in bundles articulated together, and dividing the length of the weapon into many sections. They have not the regular articulation of the articulated Khorussaunie blade, but their lines are infinitely finer. I have seen several, which were condemned for insufficient temper, submitted to the action of the engine by which they are broken. The blades were bent double and back again several times ere they could be divided. The red hue observed upon damask blades I have seen only on those of Zlatoost.

The Reaction of the Planets Upon the Sun—II*

Influence of the Earth and a Study of Sun Spots

By P. Puiseux, Member of the Institute, Astronomer at the Paris Observatory

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2046, Page 187, March 20, 1915

CHECK METHODS.

THIS result is in a way too beautiful. We had hoped to find only a small influence and we find one so decided that there is little room left for the other planets. Accordingly, search has been justly made for other proofs. We may, for instance, compare—

(1) Only the areas, in the east and west halves, of the groups of long life which have been completely followed across the disk. Here, again, without exception, for all symmetrical pairs of zones, the advantage remains with the eastern half of the disk.

(2) We may retain only the groups of long life seen in more than two successive rotations, neglecting the first and last appearances, keeping only the intermediate appearances. It is evident that in this way no appearance can be omitted or fictitious disappearance be registered. Despite these safeguards, the eastern portion still retains its advantage in the proportion of 19 parts in 100.

(3) We may substitute for the spot statistics those obtained from the protuberances observed on the east and west limbs and see if the protuberances show the same inequalities in activity as do the spots at the limb zones.

The protuberances, we have seen, follow more or less closely the solar cycle in their development. But the methods of observation for the protuberances is quite different than for the spots. Mrs. Maunder found no sufficiently complete and homogeneous series of observations of the protuberances for the interval 1889 to 1901, which her spot statistics covered. The studies of Ricco at Catania, however, cover well the interval between the last two spot maxima. Diagrams made from this data show that from 1892 to 1900, during the decrease in spot numbers, the eastern limb had on the average more protuberances than on the western limb. The opposite condition held from 1900 to 1904, but after the spot maximum was reached in 1905 the eastern limb again regained its ascendency. On the average, the eastern limb maintained a superiority of 1 to 20, less constant and less marked than in the case of the spots, but in the same sense.

Deslandres has recently pointed out a circumstance which may render the protuberances more easily visible on the east than on the west border. The sun, which we have reason to believe is electrified at its surface, must by its rotation create a magnetic field. The very mobile protuberances would be disturbed by this field so as to be bent at their upper part in the direction of the rotation. An observer would then not be in an impartial position relative to the two limbs of the sun. He will see better the oncoming protuberances which would be bent toward him than the disappearing ones which would be bent away. This hypothesis seems to be confirmed by the deformations and velocities of the protuberances.

A similar explanation is not so easy in the case of the spots. In order that they may be more easily visible on the eastern than on the western limb, we may suppose that they are followed, but not preceded, in their general rotation by some kind of a cloud. Each spot would then have its cloud, allowing the spot to be seen as it approached but hid more and more as it departed.

This explanation is not very convincing. In order that the cloud have an appreciable effect upon a great spot it would have to be at quite an elevation, and it is difficult to see how it would escape observation at the border of the sun. Its influence would not be felt except toward the ends of the spot's transit, and we have seen that the inequalities are noted in the same sense in all pairs of symmetrical zones.

(4) There remains one more test which we must not neglect. We could not pretend that the earth alone has such an influence upon the sun. If it is effective, then the other planets must be; and there are apparently three, Jupiter, Mercury, and Venus, which should be even more effective. How can we assure ourselves in this matter?

* Lecture delivered at the Conservatoire des Arts et Métiers, February 23rd, 1913. Translated from *Revue Scientifique*, Paris, May 3rd, 1913, in the Annual Report of the Smithsonian Institution.

RESEARCHES OF THE KEW OBSERVERS.

The problem had already been attacked long ago by De la Rue, Balfour Stewart, Benjamin Loewy, astronomers at the Kew Observatory. (*Proc. Roy. Soc.*, p. 210, 1872). As the observations never related to but a half of the sun at a time, it was considered necessary at the start to determine and try to eliminate the influence which the position of the observer on the earth might have. The two following conclusions resulted from the preliminary examination:

(*a*) Upon the hemisphere visible from the earth the mean area occupied by the spots increases as the distance on either side of the central meridian increases.

(*b*) The spotted surface on the average is greater on the western than on the eastern half of the visible disk.

The second conclusion of the Kew observers is at variance with that of the more recent investigators. However, the years examined in the two cases have no part in common. The data used by Mrs. Maunder was so much more homogeneous and abundant that her conclusions should have greater weight.

Having completed their first examination, the Kew observers considered how to correct their data for the position of the observer. They could then, for any planet whatever, P, compare the hemisphere turned toward the planet P with that turned away. Relative to the circle limiting these two hemispheres, any other planet, P', could have any possible position in its orbit. It seemed right to admit that, if the interval considered be long enough, the effect of P' would be eliminated and the effect of P would become evident by comparing the conditions on the two hemispheres.

It was found thus that the spotted areas tend to increase opposite to Mercury and Venus. Jupiter, upon which the greatest hope was placed, gave no definite result.

The work of the Kew observers has been rather severely criticized. The interval used seems too short for assuming the proper compensations, and the gaps in the data are considerable. The choice of the material selected has not always seemed justified.

RESEARCHES OF SCHUSTER.

In a recent memoir (*Proc. Roy. Soc.* 85A, p. 309, 1911) A. Schuster considered it advisable again to take up this problem, using the Greenwich photographs for the years 1874 to 1909. He considered only the births of spots lasting over the interval between the plates of two successive days. He excluded, as more subject to error, those births which, seen from the earth, appeared at less than 30 degrees of longitude from the eastern border. There remained 4,271 spots to consider.

For each planet P, the sun was divided into 12 equivalent vertical zones. The solar meridian passing through the planet P formed the boundary between the zones 6 and 7 on the hemisphere toward the planet and between 12 and 1 on the farther side. The number of spots seen for the first time in each zone was counted and used to form a plot having as abscissæ the zone numbers.

The results are rather irregular especially if—as Schuster did at first—we consider separately the spots counted when the earth is east or west of the central meridian. Of the three planets—Mercury, Jupiter, or Venus—each one seems to produce a minimum of spots where another may produce a maximum. If the above distinction is not made, the results seem more concordant. For all there is a minimum upon zone 3, that is when the planet is just rising, and a maximum on zone 8, which has already passed the meridian. This can be compared with the diurnal march of temperature on the earth due to the influence of the sun's heat. But there are other intermediate maxima and minima for which the three planets are in no ways in accord.

Schuster, however, considers that the similarity of march of the three curves for divisions 3 and 8 is sufficiently characteristic for rendering very probable the reality of a planetary influence.

This march is very different from that which had been found for the earth and much less definite. The effective activity of the earth is therefore apparently of another nature and relatively stronger, or it is only apparent and due to the situation of the observer.

The question was next taken up whether the distribution of spots in longitude did not become more unequal when the three planets considered, or two of them, were in conjunction for the same solar zone. The plots were remade considering only the spots born when that condition was fulfilled. No marked difference was evident. It seems as if the number of spots appearing in a zone is greater only when one of the planets in the conjunction, or slightly past it, is Venus. Schuster thinks that a planet may have merely an exciting action, effective only in putting into play a force already existing in the sun. Accordingly, a second planet on conjunction might not have any additional effect.

RESEARCHES OF F. J. M. STRATTON.

Stratton (*Monthly Notices*, 72, p. 9, 1911) thought that it would be worth while to again take up this research, considering the disappearances as well as the appearances, and retaining only those which occur at less than 50 degrees from the solar meridian passing through the earth. He considers only Jupiter and Venus, which seemed the most probable as having an influence on the spottedness. The period used was the one of 36 years, 1874 to 1909, for which the photographs of the Greenwich Observatory furnished a complete series.

The surface of the sun was divided into 24 equal zones instead of the 12 which Schuster used. The origin was the meridian passing through the planet at the moment of birth or disappearance of a spot. The zones 0 to 6 corresponded to meridians which had already passed over the planet but which are now hid from it. The zones 18 to 24 correspond to meridians which are to transit but which are still out of sight.

He then constructed for each planet plots in which the abscissæ were the zone numbers and the ordinates—

(*a*) The number of spots seen for the first time in each zone.

(*b*) The number of spots seen for the first time in the northern part of each zone.

(*c*) The number of spots seen for the first time in the southern part of each zone.

(*d*) The number of ephemeral (that is, seen for one day only) spots seen in each zone.

(*e*) Total number of spots seen either for the first time or for one day only in each zone.

This gave five curves for each planet. These were remade, using the spots seen for the last time instead of those seen for the first time; that is, disappearances instead of appearances.

The plots were very irregular. Generally there was no similarity in their contour, even for the same planet, between the two hemispheres; neither was there between the same hemispheres for different planets. There is one single coincidence, perhaps, which seems not due to chance. There is a maximum of ephemeral spots noted in the zones the meridians of which either Jupiter or Venus had already passed three hours previously.

It is notable that for this interval of 36 years a terrestrial observer always notes in the central region of the sun more disappearances than appearances. The difference reaches 10 parts per 100. This agrees with what Mrs. Maunder found for the interval 1889 to 1901. For Jupiter and Venus the births seem more frequent when the planet is above than when under the horizon, that is, in the opposite sense from what Mrs. Maunder found for the earth. But the difference is very small and merits no physical explanation.

The relation between the east and west hemispheres of the sun, as seen from a planet, is for Venus in the opposite sense than is the case for the earth. In the case of Jupiter there is scarcely any difference, as the following table shows:

Spots seen on the hemisphere of the sun toward a planet.

	East half.	West half.
Jupiter	8,792	8,711
Earth	8,213	7,508
Venus	7,834	8,368

Another comparison may throw some light on the matter. When a planet is on a given side of the equator is the hemisphere on the same side as the planet especially favored with spots? The reply is contained in the following table:

Planet.	South, number of spots.		North, number of spots.	
	South.	North.	South.	North.
Jupiter	8,419	5,621	5,785	5,931
Earth	1,512	1,254	1,485	1,329
Venus	6,931	5,750	7,381	6,212

This table seems significant if only the left half is considered. But the preponderance in the southern hemisphere continues whether the planet is to the south or to the north. That is, in the interval considered, the southern hemisphere of the sun had habitually more spots. This may be due to causes within the sun and to no influences from the planets.

This simple comparison leads us to suspect that the concordances noted in the plots for the various planets may be due to causes within the sun. There are two possible reasons for the inequalities in the plots:

(*a*) Any given zone relative to the planet can remain invisible from the earth for months.

(*b*) The epoch when a particular planetary zone may be favorably seen by a terrestrial observer may fall sometimes in the spot maximum phase, sometimes in the minimum phase.

The second perturbing effect is graver than the first. The period of 36 years embraced by the Greenwich data is not sufficiently long to assure us that these two sources of error are eliminated. The method should not be abandoned, but we must get more observations.

CONCLUSIONS.

It would be presumptious to say that we have unveiled the mode in which the planets may react upon the sun, but we feel persuaded that some reaction exists and that it will not always elude us. The sun may have within itself the reason for its period, but it does not keep to itself its rythmic action. It has not sufficient store of energy in the mutual attraction of its parts, in its rotation or in the active force of the planets, there remains a resource in the cosmic dust. Perhaps it is not the matter condensed into the shining stars but that which is scattered in impalpable particles throughout space which contributes more to the stability of the universe.

It seems to me that these views suggested by the study of the heavens help to keep us even in every-day life from discouragement and indifference. The historian, whose attention is focused on salient events, may believe that the human race exists only for a few marked men. The naturalist, accustomed to note the annihilation of the weak, cries willingly with the poet, "Le vent n'ecoute pas gemir la feuille morte" (The wind hears not the sigh of the lifeless leaf). But that is only apparently true. The dead leaf, in its manner and measure, reacts on the wind. Already religious moralists warn us that every act, no matter how small and weak, has a sovereign value when it is done in conformity with the eternal order. And this conclusion will not surprise the geometrician, who is constrained to weigh all in an impartial balance and recognizes in the smallest corner of the universe an unlimited influence with regard to space and the future.

Fuel Oil on Railroads*

It has been customary to gage the use of oils for fuel in the United States largely by the consumption by railroads, because the statistics of such consumption may, by careful inquiry, be obtained with approximate accuracy, while consumption in other lines of industry is extremely difficult of determination.

The use of fuel oil by the railroads of Texas was originally due to the sudden flood of cheap oil from the Beaumont region in 1901. The continuance of this trade has lately been aided by imports from Mexico. The ease with which these Texas oils can find other markets than the railroads and the fact that the railroads can return to coal without very serious disadvantage make the future of locomotive consumption of fuel oils in Texas uncertain.

In California the railroads were the first to absorb large quantities of California oils. This legitimate use has become permanent from lack of other fuel, and it has extended to other kinds of generation of power, including marine transportation for shipments coastwise and to foreign countries.

A serious menace to the continued use of oil for fuel in California is the recent change in the character of the crude oils of that State. Many of the new pools yield oils suitable for refining and for the production of large quantities of gasoline and kerosene. Up to the beginning of 1913, about 30 per cent of the oils of California were refined and the rest was sold for fuel as crude or after very light distillation of the lightest products. This practice changed materially during 1913, so that the proportion of crude oil used direct as fuel became reversed, and, although no accurate figures are available, 70 per cent is about the proportion of crude oil which was refined during that year before the heavier portions were sold for fuel. The result of this, however, will be not to decrease the use of oil for fuel, but to change the method of its application, particularly to the internal combustion engine burning kerosene and heavier distillates.

Although the use of fuel oil extended to a greater number of miles of railroad, the quantity of oil consumed by these railroads decreased slightly and the total mileage made by oil-burning engines decreased in similar proportion, leaving the average number of miles made per barrel of oil consumed the same in 1913 as in 1912.

If it were possible to give a complete statement as to the tonnage moved per barrel, it would undoubtedly show an increase on account of the heavier trains moved, which is offset as to consumption of oil by the increased efficiency of new oil burners, arrangement of oil tanks, and increased skill developed by the firemen.

During 1913 three railroad companies discontinued the use of fuel oil and returned to coal, impelled not only by the advancing tendency of fuel oil prices, but by direct notification from refineries that continuation of contracts would be impracticable. The increase in demand for light products from crude oil has reduced the volume of residuum available for locomotive and other fuel use to a point approximating only 30 per cent of that obtained when gasoline was not in strong demand.

* From the report of the United States Geological Survey on the Production of Petroleum in 1913.

Photographing Projectiles—I*

Securing Records by Means of Illumination from Electric Sparks

THE following article is for the purpose of enlarging upon the methods adopted in 1887 by Prof. E. Mach, in collaboration with P. Salcher and L. Mach, for obtaining photographs by means of the electric spark.

Mach's electric spark photography has been so widely quoted in all sorts of technical periodicals, that its fundamental principles may now be considered as generally known. E. Mach himself employed for his photographs a condensing lens, that is to say, a concave mirror in conjunction with a camera. V. Boys at a later date (1896) modified Mach's methods by obtaining, by means of the electric spark, simple shadow pictures (silhouettes) of approximately full size upon sensitized plates, without using concave mirrors or lenses. The methods are similar in that a shadow picture of the object is obtained, that is to say, a silhouette, in which the outline alone of the various objects appears. Examples of such silhouettes are shown in Figs. 1 to 7.

Fig. 1, a print made by the simple shadow method of V. Boys, shows an automatic pistol at the moment of discharge.

Figs. 2 to 6 are photographs taken by the Mach process in conjunction with the Töpler obscuration, or light reducing, process.[1]

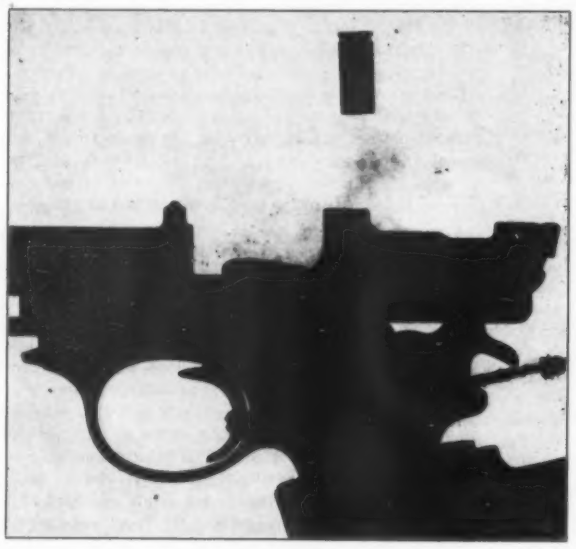


Fig. 1.

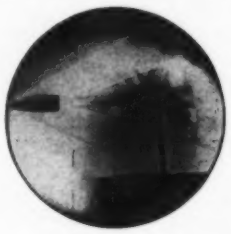


Fig. 2.

Fig. 3.

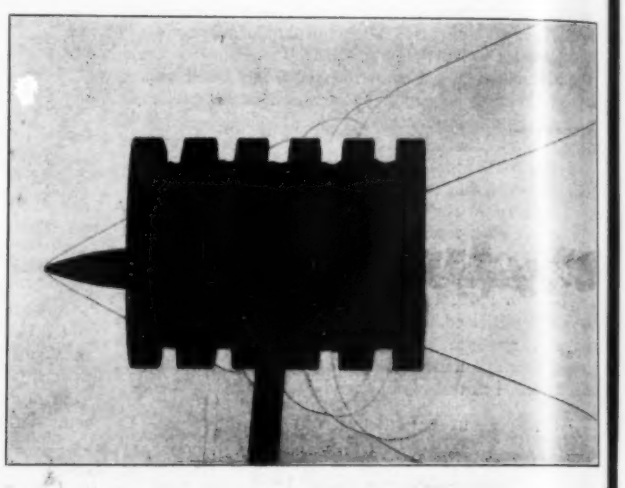


Fig. 7.

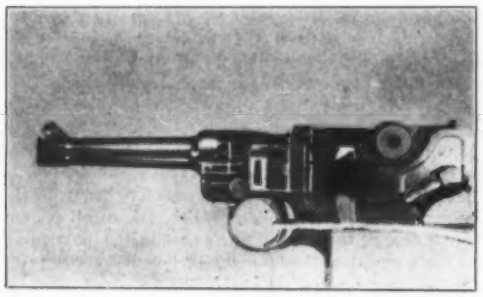


Fig. 9.

Fig. 4.

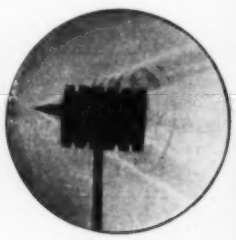


Fig. 5.

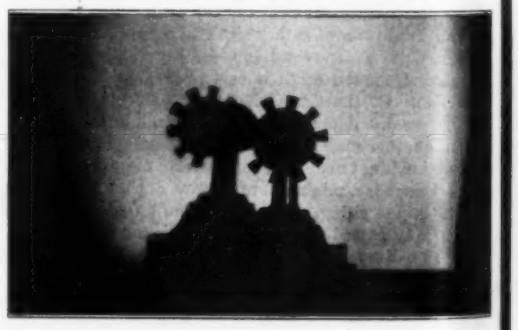


Fig. 8.

Fig. 10.

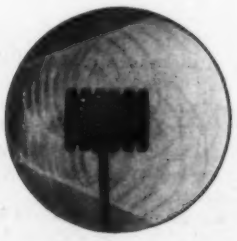


Fig. 6.

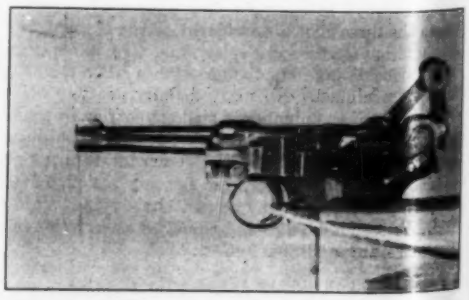


Fig. 11.

Fig. 1, a print made by the simple shadow method of V. Boys, shows an automatic pistol at the moment of discharge.

Figs. 2 to 6 are photographs taken by the Mach process in conjunction with the Töpler obscuration, or light reducing, process.[1]

Fig. 2 shows a small-arms bullet, with head waves, tail waves, and eddies behind the bullet; the photograph was taken with a slight degree of obscuration (*abblendung*). The bullet has just perforated a screen. Fig. 3 represents the same with a stronger obscuration; here the bullet has almost passed beyond the field of view. At the place where a little wooden screen has been perforated by the bullet, an impact wave of air has broadened out to spherical form; and the same thing has occurred at the corner of the table on which the little wooden screen stands; also, the position of discharge of the electric spark is visible at the extreme right edge of the field of view. The headwaves are reflected by the table top according to the law of mirrors. In Fig. 4, the bullet has passed through a metal tube. The waves which originally accompanied the projectile have been cut off by the tube, and appear as sections of circular arcs, which was naturally to be expected. After passage through the tube the waves have formed anew.

Similar photographs were earlier obtained by T. Terada and M. Okōchi in Tokio (see the Japanese periodical *Tokyo Sugaku-Buturigakkwai Kizi*, 2d series, Vol. IV, No. 20, 1908, page 402, and Plate II, cuts 13 to 15).

Figs. 5, 6 and 7 were obtained in the Laboratory for Ballistic Instruction. It is to be observed that the head and tail waves are to be considered as envelopes of Huyghens' elementary waves. The bullet passes through a metal tube open at the ends and perforated above and below with many holes. We see in Fig. 5 how the elementary waves formed by the holes are enveloped by the head wave. Fig. 6 is the same taken an instant later; here the tail wave forms an envelope for the elementary waves. Fig. 7 is the same as Fig. 5, except that it is taken by the simple shadow method, without mirrors and lenses.

The shadow methods employed by Mach and Boys cannot be dispensed with, when it is a question of obtaining photographic records of air waves and eddies; for then difference in refractive power (*schlieren*) must be dealt with. On the other hand, where difference in refractive power (*gaschlieren*) does not enter, but it is a question merely of the details of an opaque body, from a ballistic point of view photographs made by ordinary methods are quite satisfactory. In such photographs, as is well known, the face of the object which is toward the camera is illuminated by direct or indirect rays of the sun or some other source of continuous light; but if the object to be caught is in very rapid motion, when continuous illumination is employed, sufficiently instantaneous closing of the shutter must be assured; and while it is possible to obtain in ordinary instantaneous photography an exposure of 1/20,000 of a second, yet even that brief interval is far too great for obtaining sharp definition in the case of many mechanical movements, and especially in the case of those with which we are concerned in ballistics. When, for instance, a wheel of 500 millimeter circumference revolves at a rate of 12,000 revolutions per minute, a point on the circumference has passed over a distance of 5 millimeters in 1/20,000 of a second; so, if the wheel is photographed

*By C. Cranz, P. A. Günther, Captain, 49th Regiment, Field Artillery, and F. Külp, Captain, 118th Regiment Infantry. Translated from the *Zeitschrift für das Gesamte Schiess- und Sprengstoffwesen* for the *Journal of the United States Artillery* by Charles A. Junken.

[1]The editor of the *Zeitschrift für das Gesamte Schiess- und Sprengstoffwesen* has kindly explained that this process (*Töpler Schlierenabblendung*) consists in darkening the field of view by means of a blackened metal block advanced so far toward the axial line of the camera lens as to cause the field of view just to begin to show dark. (*Schliere*, a space in which the refractive power differs from that of the surrounding medium; *Abblendung*, obscuration.) —Tr.

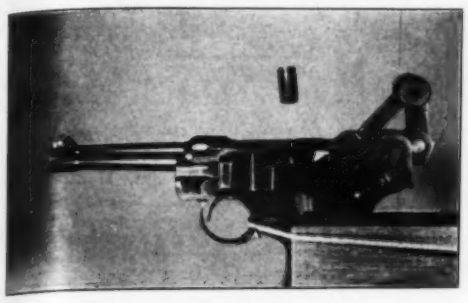


Fig. 12.

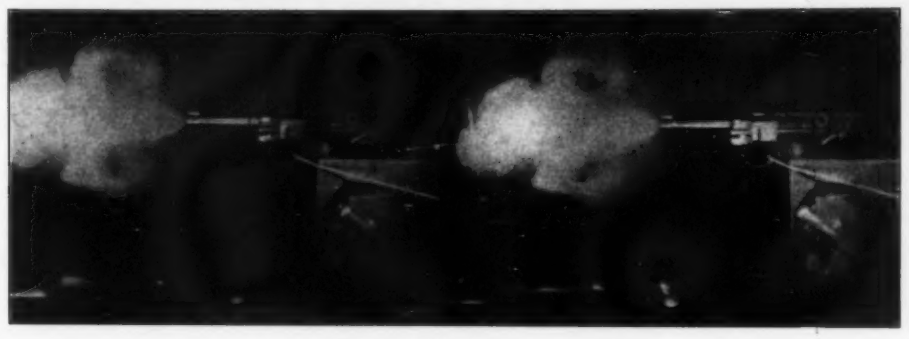


Fig. 13.

to half size, the definition of a point on the circumference is reduced by its extension through 2.5 millimeters. If a projectile is traveling at the rate of 900 meter-seconds and is photographed to 1/10 its natural size, the definition of a point is reduced by its extension through 4.5 millimeters, since the projectile moves during the exposure 45 millimeters. On the other hand, sufficiently instantaneous exposure is attainable in illumination by means of an electric spark, the duration of the spark light, determined by various methods, being from 1/3 to 1/10 of a millionth of a second.

The method for obtaining a photograph by the light of an electric spark is naturally similar to that employed for securing a photograph of a stroke of lightning on a dark night: the camera is opened till the light shines, and is then closed. C. Cranz in 1909 obtained some negatives by illuminating the face of the object with the electric spark (see *Zeitschrift*, etc., Vol. 4, of 1909, page 323), the spark being discharged through a mercury arc-lamp. Very clear pictures were subsequently published by Herr H. Boas in Berlin, in a privately printed pamphlet, in which the face of the object was illuminated by spark light, a reflector being employed. Among other things, he photographed a revolving wheel (Fig. 8).

By employing a great number of condensers we have lately resumed experiments with face illumination; and in Fig. 9 and those following, we shall, by means of many examples, show that, in face illumination with spark light, details within the contour of rapidly moving objects appear with thoroughly satisfactory definition. Some of those photographs we published in July of last year in *Schuss und Waffe*, Vol. 6, No. 20, page 397; and by arrangements with the editors of both periodicals concerned we republish in the present article, the earlier photographs with slight changes in the accompanying text, and give, in addition, a new series of photographs of ballistic, scientific, or physical interest, as well as some stereoscopic photographs and moving picture films.

The condensers were thoroughly charged by means of a static machine, the available capacity being 45,000. For making Fig. 17, a capacity of about 3,500 was employed. In order to eliminate solitary shadow effects, at least two to four illumination sparks were discharged in series to the right and left of the object to be photographed, and in front of the camera.

The illumination from that spark which corresponds to the final stroke of the battery, due to self-induction, is the shortest and weakest flash.

In addition, small concave mirrors were placed behind the lighting area; moreover, several successful photographs were obtained by means of light projectors placed at greater distances from the object.

One or the other position of the sparking areas should be adopted according to the requirements; they will naturally vary with the methods adopted for discharging the illuminating sparks.

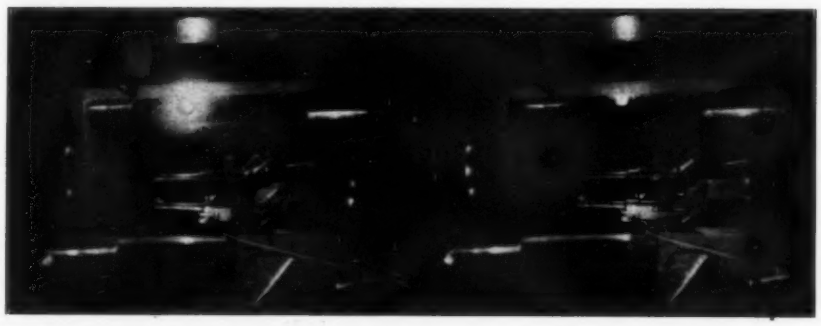


Fig. 14.

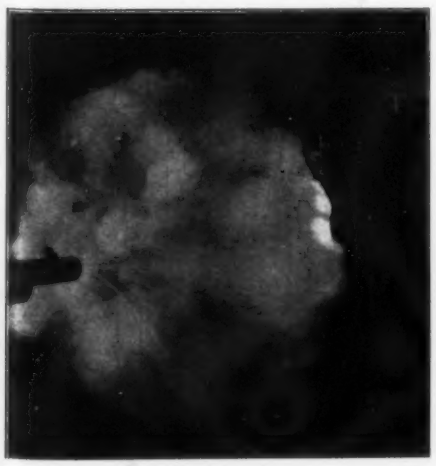


Fig. 14 II.

Fig. 9 represents the army pistol in a state of rest before firing. On the pistol housing in front of the rear end of the barrel and in rear of the breechblock may be seen vertical marks drawn with a white pencil. From the shifting of these vertical marks we may readily determine, at any instant, whether the piece has been fired, how far the breech mechanism has recoiled, etc.

Fig. 14 I.

Fig. 10 represents the same pistol during discharge, that is, at the moment when the bullet is 8 centimeters from the muzzle. Powder gases are streaming from the muzzle, and within the powder gas may be seen the position of discharge of the electric spark.

Fig. 11 represents the same pistol at the instant when the bullet is 200 centimeters from the muzzle. The extractor is partially open.

Fig. 12 shows the same pistol when the bullet is 350 centimeters from the muzzle. The empty cartridge case has been extracted and thrown into the air.

Fig. 13 is a double, or stereoscopic, photograph of the same pistol in firing; the powder gases are streaming from the muzzle.

Fig. 14 is a double, or stereoscopic, photograph of the same pistol in firing and its reflected image. In this, not only the pistol itself, but its reverse reflection in the mirror is visible, so that we may observe at the same instant both sides of the weapon. Such photographs have a peculiar value when we are dealing with an automatic arm, because from the front side the action of the extractor is followed with great difficulty. They are also of value in the case of small projectiles, when measuring rotation of the projectile, its oscillations, etc.

Fig. 14 I shows the blast of the black powder gas at the muzzle of the small arm, Model 71, seen from the front. The larger volume of the powder gas is expanding in the form of a mushroom, while in front of this mushroom may be seen that portion of the gas which has been drawn forward by the bullet. By its form the mushroom clearly shows how the rifling has affected it. The several bright lines are the trajectories of the burning powder grains.

Fig. 14 II shows the same taken from the rear, and to one side.

Fig. 14 III is a stereoscopic, or double, photograph of the same phenomena. Examination with the stereoscope affords an exceedingly realistic view of the form of the mushroom and the trajectories of the burning powder grains. For this reason, it may be remarked, many photographs of small shot (not reproduced here) were obtained by stereoscopic methods. Stereoscopic examinations of the shot sheaf permitted such an accurate separation of the individual shot in the direction of the three dimensions, that it was found possible, by means of the stereoscopic scale, to determine not only the extent of separation of the flying shot, but also, from many successive photographs, the reduction in velocity and the rotation of the individual shot. It is probably feasible by such methods to solve many problems which are at present shrouded in mystery. We hope to recur to these matters.

(To be continued.)

A Quality of Electrolytic Iron

If a sheet of electrolytic iron and one of ordinary rolled iron are cleaned of scale and oxide and set up as a battery with dilute sulphuric acid, a millivoltmeter will show that the electrolytic iron is electro-positive to the common iron. It will be appreciated from this that a coating of electrolytic iron is under many circumstances a desirable protective coating.

Fig. 14 III.

Making Steel by Electricity*

Various Systems; Their Merits and Defects

THE idea of producing steel by electrical methods is more than 60 years old, but no practical solution of the problem was achieved until the close of the last century, when electric furnaces of several distinct types were put into operation.

The oldest of these furnaces, the Stassano furnace (1898), in which the metal is heated entirely by radiation from an electric arc, is now used chiefly for the production of small steel castings, weighing less than 2 tons. It is well adapted for small machine works which make their own castings, and for all cases in which it is undesirable, for any reason, to intrust the work to an outside foundry.

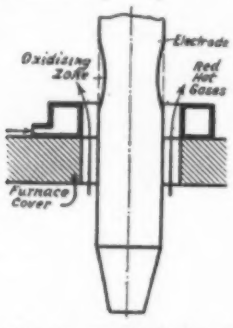


Fig. 2.—Oxidized electrode.

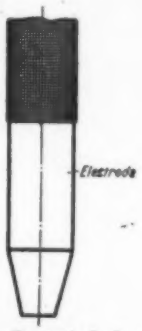


Fig. 3.—Protected electrode.

At nearly the same time appeared the Héroult furnace with two or three vertical electrodes placed immediately over the metal. This is the most widely used of all electric furnaces. It is suitable both for fusing cold scrap and for refining molten metal, and it is employed in many steel works in capacities up to 25 tons.

The Girod furnace, with one electrode above the metal and one or more in the bottom of the furnace, was first designed (1906) to use monophase alternating current, but it was subsequently adapted to the employment of triphase current also. Its field of usefulness is the same as that of the Héroult furnace, but no Girod furnace of greater capacity than 15 tons has yet been constructed.

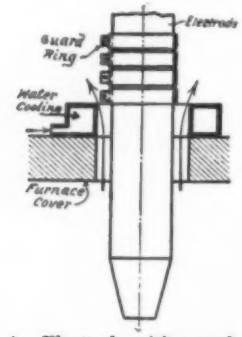


Fig. 4.—Electrode with guard rings.

The Keller furnace, based on a similar principle, is used chiefly in France, and far less extensively than the Girod furnace.

The Nathusius furnace, which appeared in 1908, differs from all other furnaces with bottom electrodes in allowing a current to be established between the bottom electrodes, as well as between them collectively and the upper electrodes. In this way the distribution of heat through the charge can be varied at will. The largest Nathusius furnaces yet constructed have a capacity of 10 to 12 tons. The field of utility is similar to that of the Girod furnace, but the Nathusius furnace is said to be peculiarly well adapted to the smelting of ferromanganese.

Many other electric arc furnaces have been patented, but they differ little from those mentioned above, or from each other.

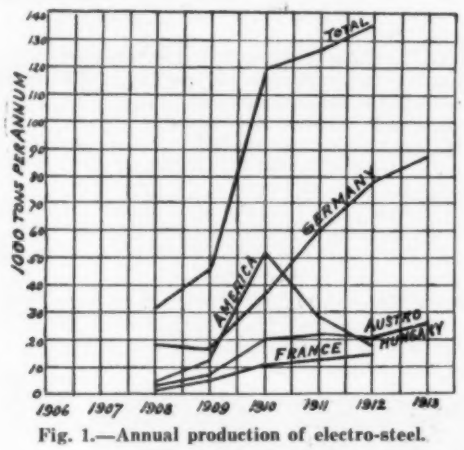


Fig. 1.—Annual production of electro-steel.

Toward the close of the last century, almost simultaneously with the arc furnaces, appeared the first induction furnaces, the Kjellin and the Frick, which differ only in the form and arrangement of the primary coils. The Kjellin furnace may be used in place of the crucible furnace, but it is not very well adapted for refining and it has serious defects which have greatly limited its field of application. Until recently this was equally true of the Frick furnace but the latest form of the latter is said to be very well adapted for refining, and several large Frick furnaces, including two of 20 tons capacity in America, are being constructed for the production of fine steel from molten metal.

The Roechling-Rodenhauser furnace was created in 1906 by combining a number of Kjellin furnaces. (The new Frick furnaces are also of the combined type). The Roechling-Rodenhauser furnace was the first induction furnace employed at all extensively. It is now used chiefly for refining molten metal and for smelting ferromanganese. The largest of these furnaces yet constructed have a capacity of about 12 tons.

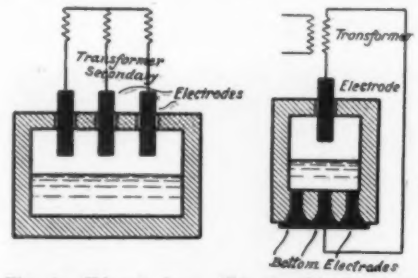


Fig. 6.—Héroult furnace.

Fig. 7.—Girod furnace monophase current (1906).

Many other induction furnaces have been patented and attempts have been made to combine induction heating with arc heating or with resistance heating.

As nearly as can be ascertained the total number of electric steel furnaces in existence, and in process of construction, in 1913-14 was 173, of which 138 were arc furnaces and 35 were induction furnaces. The arc furnaces included 67 Héroult, 27 Girod, 9 Nathusius, 10 Stassano, 6 Keller, 8 Chaplet, and 11 others. The induction furnaces included 10 Kjellin, 17 Roechling-Rodenhauser, 6 Frick and 2 others.

The following table shows the number of tons of electro-steel produced in various countries in the years from 1908 to 1913, inclusive:

	1908	1909	1910	1911	1912	1913
Germany and Luxemburg	19,536	17,773	36,188	60,654	79,190	88,881
France	2,289	6,456	11,759	13,850	15,922	?
Austria-Hungary	4,533	9,048	20,028	22,867	21,556	26,837
America	6,112	13,762	52,141	29,105	18,602	?
Total	32,590	47,039	120,116	126,476	135,270	?

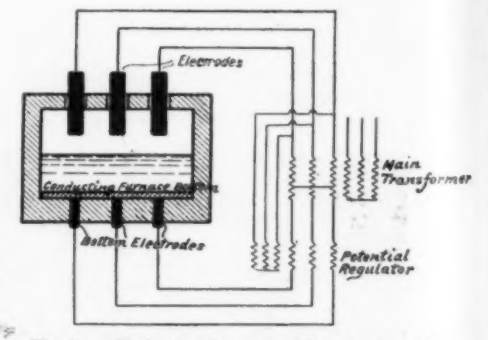


Fig. 9.— Nathusius furnace with patent regulator.

From this table and the corresponding graphical record (Fig. 1), it appears that the annual production, though increasing in Europe, has steadily declined in America since 1910. In general, it is evident that the electric furnace is far less extensively employed than would be expected of a new device of demonstrated practical utility. This slowness of development is due chiefly to the two following causes:

In the first place, at the prevailing prices for electric current the electric furnace can compete successfully with other furnaces only in the production of high grade steel, and even here only when electric energy is comparatively cheap and other conditions are favorable. It is the superior quality of electro-steel that makes successful competition possible. Steel of lower grade can be produced more easily and cheaply by other methods.

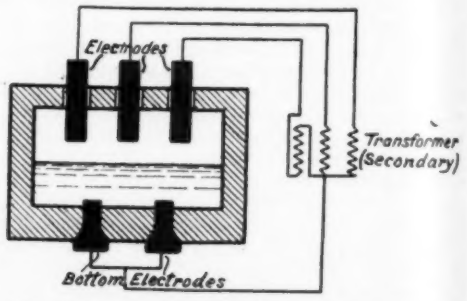


Fig. 10.—Girod furnace for three-phase current (1911).

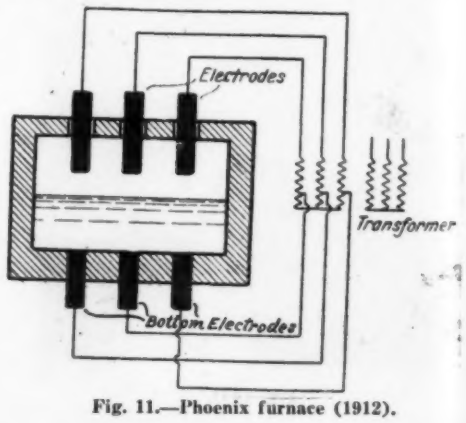


Fig. 11.—Phoenix furnace (1912).

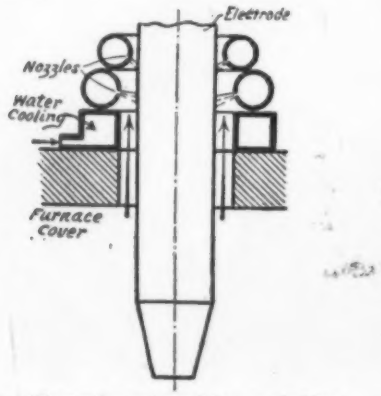


Fig. 5.—Electrode protected by an air blast.

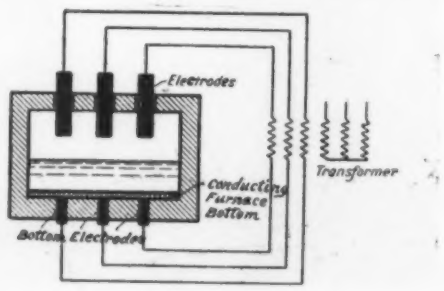


Fig. 8.—Nathusius furnace (1908).

* Abstract of Dr. Sigmund Guggenheim's article in *Elektrotechnisce Zeitschrift*

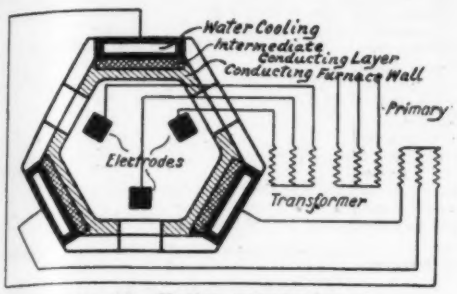


Fig. 12.—Hardén furnace (1912).

In the second place it is very difficult to construct an electric furnace of a capacity exceeding 15 tons. The largest charge now worked is 25 tons and the practical utility of the largest electric furnaces has not been conclusively demonstrated.

An electric furnace can find extensive employment only on condition that it can be connected to a normal triphase circuit of several thousand volts and 50 periods, without the interposition of rotary converters, and even static transformers should be eliminated, if possible. At present this condition is satisfied only by Roechling-Rodenhauser furnaces of less than 4 tons capacity. Larger furnaces of this type and all other induction furnaces require, for economical operation, currents of low frequency (5 to 25 periods). Induction furnaces in general require special generators or rotary converters, which greatly increase the cost of installation.

Arc furnaces usually dispense with rotary converters, as they can use a current of 50 periods if the conductors are properly arranged, but they generally require transformers, as they are constructed for low voltages. All arc furnaces have the defect that the heating current of thousands of amperes, which in induction furnaces is generated in the charge itself, must be brought in from an external source. A charge of 15 tons requires a current of about 15,000 amperes, and the conduction of the still stronger currents required for charges exceeding 30 tons presents difficulties that have not yet been overcome.

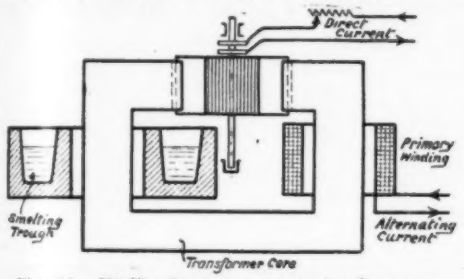


Fig. 13.—Kjellin furnace with device for regulating factor of efficiency.

One of the greatest difficulties is met in the construction of the electrodes. Large electrodes usually carry 6 or 7 amperes per square centimeter, so that a circular electrode carrying 20,000 amperes would have a diameter of 63 centimeters (about 25 inches). Homogeneous electrodes of these dimensions are very difficult to produce and rapidly disintegrate.

The life of the electrode is shortened by oxidation. In order to allow the electrodes to be pushed down as they are consumed at the lower end they must pass through the furnace cover with some clearance, through which burning gases escape and oxidize the upper parts of the electrodes (Fig. 2). When the gradual lowering of the electrode brings this partly consumed portion to the furnace cover the clearance and the evil are increased. For his reason it is customary to protect the upper portion of the electrode by a water-cooling device (Fig. 2), or a collar of wire netting coated with cement (Fig. 3), or both.

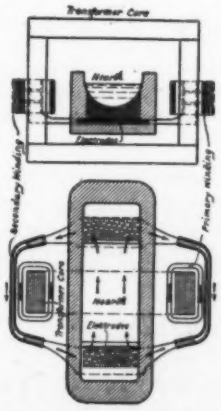


Fig. 14.—Vertical and horizontal sections of first improved Roechling furnace (1912).

The insufficiency of these precautions is proved by the number of recent patents for improved methods of protection. The preparation of the electrodes is very laborious, as the cement-coated netting must be applied in the moist state and allowed to dry on the electrode. For this reason one firm proposes to substitute for the netting a number of separate and easily removable guard rings of refractory material (Fig. 4). Another patent covers the suppression of the outflow of furnace gas by a counterblast of air or steam from nozzles surrounding the electrode (Fig. 5).

The arrangement of the electrodes in various arc furnaces is illustrated in Figs. 6 to 12. All, except the Héroult and Stassano furnaces, employ bottom electrodes. The bottom electrodes of the Girod furnace have the same potential, so that no current flows between them, but those of the other furnaces have different potentials and produce currents in a conducting layer of the furnace bottom or wall.

In the Héroult furnace the heating effect is produced entirely by the arc above the charge. To this the Girod furnace adds the heating effect of the current through the charge, and the Nathusius adds also the heat produced by the current in the furnace bottom. This bottom heating can be varied within wide limits by means of a potential regulator and in this way the load on the upper electrodes can be diminished.

The defects of the induction furnace are even greater than those of the arc furnace. The electrical defects of the former have already been mentioned. Its most serious metallurgical defect is the absence of a simple closed hearth. The melting troughs of the Kjellin and Frick furnaces are not very well adapted for refining, and even the combination of several such troughs in the Roechling-Rodenhauser furnace is not entirely satisfactory for this purpose. Another defect of the induction furnace is the impossiblity of melting cold charges without the aid of special auxiliary devices.

Attempts to increase the efficiency of the induction furnace have been made by increasing the resistance of the melting troughs, by adding other resistance heating to the inductive action, and by modifying the arrangement of the primary coils. A Baden firm has tried to improve the efficiency of the Kjellin furnace by a radically different method (Fig. 13). The transformer core includes a disconnected segment which is capable of rotation and is energized by a direct current flowing through an enveloping coil. The primary cost of the furnace is connected as usual, with an alternating circuit. This arrangement constitutes a synchronous motor, so that the magnetized segment, if it is rotated in synchrony with the alternating current, will continue to rotate at the same speed. The primary difference of phase can then be regulated at will by modifying the exciting direct current.

Attempts to melt cold charges in induction furnaces have proved equally futile. The introduction into the melting troughs of iron rings to serve temporarily as closed secondary circuits is troublesome and it is usually inadmissible, for chemical reasons, in the production of high grade steel.

Special attention has been given by inventors to the construction of a hearth suitable for metallurgical purposes, and many patents have been issued in this field. The Roechling steel company has patented two furnaces with simple closed hearths (Figs. 14 and 15). In the standard Roechling-Rodenhauser furnace only a small portion of the secondary current is produced in a secondary wire coil and communicated to the charge through electrodes, but in the new Roechling furnaces the whole of the heating current is so produced and communicated. Hence these furnaces are not induction furnaces, but resistance furnaces operated by transformers. The peculiar advantage of the induction furnace, the generation of the strong heating current entirely in the charge itself, is forfeited, and the advantage of the simple hearth without troughs is offset by the necessity of constructing external conductors and electrodes capable of carrying the strong current safely and efficiently.

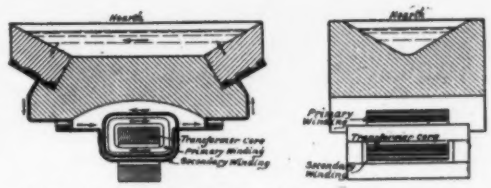


Fig. 15.—Longitudinal and transverse vertical sections of second improved Roechling furnace (1912).

On the whole it appears that the induction furnace, at present, is even more deficient than the arc furnace in the qualities requisite for extensive employment. This is probably one reason why the number of induction furnaces increased only from 30 to 35 between 1908 and 1913, in which period the number of arc furnaces increased from 43 to 138.

The advocates of the arc furnace assert that a thin-flowing slag, of higher temperature than the metal beneath it, is absolutely necessary for good metallurgical work, and that this condition is satisfied only in the arc furnace where the heat is produced at the surface. In the induction furnace the heat is generated in the metal which, consequently, must be hotter than the slag. It is possible, however, to raise the temperature of the charge in the induction furnace far enough above the fusing point to produce a thinly-flowing slag.

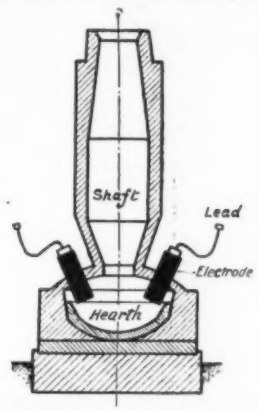


Fig. 16.—Swedish electric ore-reducing furnace.

The electrical reduction of iron ore has recently been attempted, and with some success. In Scandinavia and California, where water power is cheap, this method has been profitably employed for several years.

Most of the experiments in the electric production of pig iron have been made with arc furnaces. Stassano's first furnace was designed for the reduction of iron ore. Subsequently Keller and Héroult experimented with arc furnaces but the first practical success was obtained in Sweden by Groenwall, Lindbad and Stalhane, whose experiments began in 1907.

The ore-reducing furnace of Groenwall, Lindbad and Stalhane (Fig. 16) is very similar in form to the ordinary blast furnace. Experiments with these furnaces are now being conducted on a large scale but the results yet obtained do not absolutely assure commercial success.

In Germany, Helfenstein has obtained good results with both arc furnaces and induction furnaces. His induction furnace, like the new Roechling furnace, is essentially a resistance furnace in which the charge forms part of the secondary circuit of a transformer.

Among the many patented systems of electric ore-reduction one of the most interesting is that of Hering, who employs the resistance furnace shown in Fig. 17. Fusion takes place in the two lower shafts, from which the molten metal is continuously expelled by the so-called Pinch effect, first made known by Hering, and is replaced by fresh material entering through lateral channels. Fig. 18 shows this furnace combined with a steel furnace into which the molten iron is discharged.

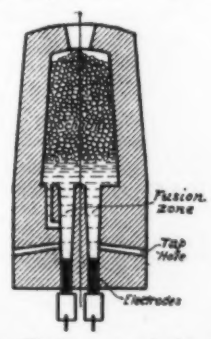


Fig. 17.—Hering ore-reducing furnace (1913).

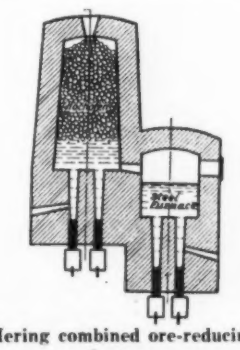


Fig. 18.—Hering combined ore-reducing and steel furnace.

NEW BOOKS, ETC.

SCIENCE AND METHOD. By Henri Poincaré. Translated by Francis Maitland. With a preface by the Hon. Bertrand Russell, F.R.S. London and New York: Thomas Nelson & Sons.

While there is much in this book of the wonderful Poincaré which will be understood and appreciated at its true worth only by the mathematician, there is also a wealth of material which must make its appeal to the general reader. There are general papers on science, on astronomy, and on radium which will awaken the interest of every thinking man. The essays on mathematical reasoning, by far the finest in their way which have come to our notice in many a year, make a special appeal which cannot be ignored. The whole book is a collection of various studies which the late Prof. Poincaré made in scientific methodology. The Hon. Bertrand Russell has written a Preface in which he sympathetically sets forth the significance of Poincaré's work in this age. One must endorse his estimate of Poincaré's writings. "It has the freshness of actual experience," Mr. Russell asserts with justice, "of vivid intimate contact with what he is describing. . . . His wit, his easy mastery, and his artistic love of concealing the labor of thought, may hide from the non-mathematical reader the background of solid knowledge from which his apparent paradoxes emerge: Often, behind what may seem a light remark, there lies a whole region of mathematics which he himself has helped to explore."

AIR CRAFT IN WAR. By J. Spaight. London and New York: Macmillan & Co., 1914. Price, $2.

Dr. Spaight's book consideres the military uses of flying machines and airships from the standpoint of international law. His book appears most opportunely, although unintentionally so, in view of the fact that since it was written Zeppelins have dropped bombs on Antwerp, and aeronautical machinery has at last been tested. The situations which Dr. Spaight discusses have already arisen in the present conflict. Thus, for example, he considers the right of an airship to drop bombs upon an undefended city, containing barracks, military stores, and railway stations—in other words, the Antwerp situation. He finds nothing in international law which could prevent an airship from attacking a town in this fashion. He discusses also the rights of neutral airmen in war zones and finds that they venture within the danger line at their peril. His analysis of the Hague Convention and its influence upon aerial bomb-dropping is illuminating. He considers the provisions against bomb-dropping in the convention moribund, and prophesies that they will be dropped altogether when the next Hague Convention is called. His analysis was written before the war. Recent events lead us to suppose that the opposite effect will result. In some interesting appendices Dr. Spaight discusses various codes which have been proposed from time to time to govern the movements of aircraft in time of war and peace. The well-known code of Fauchille, which was drafted before the aeroplane and airship became such military necessities, comes in for much criticism. Dr. Spaight offers a code of his own which it must be confessed has distinct advantages over that of Fauchille.

ANLAGE UND BETRIEB VON LUFTSCHIFFHÄFEN. Von Dipl. Ing. Christians. München und Berlin: Verlag Oldenbourg, 1914.

It was the Germans who first gave the subject of airship sheds anything like systematic engineering attention. The reason is not far to seek. It was really not until the giant Zeppelins made their appearance that the housing of airships presented any great difficulties. It was no difficult matter to store Parsevals and similar collapsible balloons. The importance of the airship shed has been driven home primarily by the numerous accidents which have been sustained by Zeppelins—accidents nearly all of which have been caused by trying to run a rigid airship into a shed during a gale. In this admirable book of Engineer Christians, all the experience gained by German airship builders and navigators in housing airships is concentrated. So far as we are aware, it is the first trustworthy setting in print of a problem which demands serious attention, now that the Zeppelin airship has come to stay. The United States is still so backward in aeronautics, particularly in the development of the dirigible, that Engineer Christian's book will have more of an academic than a practical interest for our aeronautic engineers; but the time is not far distant, we venture to prophesy, when its pages will be eagerly scanned in this country in order to reap the fruit of German experience.

EVERY MAN HIS OWN MECHANIC. A complete Guide for the Amateur to All Constructive and Decorative Work. By John Barnard. New York: Frederick A. Stokes Company. 8vo.; 504 pp.; fully illustrated. Price, $1.50 net.

Of British authorship, this work differs slightly in both nomenclature and method from American usage. In all other respects it will be recognized as a reliable guide to the amateur carpenter, metal worker, plumber, paperhanger and palsterer. The use of tools is naturally given extended consideration, and all kinds of work in wood are given adequate space. Such subjects as inlaying, marquetry and the more advanced handicrafts are simply outlined in suggestive paragraphs. Its appeal is avowedly to the man who takes up some constructive work as a hobby, and to judge it according to the standard demanded by a professional handbook would be an injustice. In its own field it will prove of material aid to the tyro, furnishing hints for household repairs and furnishings that will delight his heart.

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